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A framework for organizational performance assessment in the construction industry

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A FRAMEWORK FOR ORGANIZATIONAL PERFORMANCE ASSESSMENT IN THE CONSTRUCTION INDUSTRY

A Thesis

Submitted to the Faculty

of

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Zenith Rathore

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of

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For my family

for their unconditional love and support

who forever inspired me to reach the zenith

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ABSTRACT

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Organizations have been trying to increase their efficiency and improve their performance in order to achieve their goals. Organizational success is determined by various factors. Construction industry is a project based industry which is extremely dynamic in nature. The need to identify the weak points and search solutions to improve performance of construction organization is extremely crucial. Industry has always focused on measure of project success. Previous research works have primarily focused on the measurement of financial or tangible assets.However, previous studies lack the understanding of qualitative factors and their combine effect on organizational performance. Therefore, the objective of the present research is to identify and study the success factors - both financial and non-financial factors. The potential success factors are collected from literature and construction experts through a questionnaire that is prepared and sent to evaluate the effect of these potential success factors on organizational performance. The collected data is analyzed using Analytic Hierarchy Process (AHP) to shortlist the critical success factors. Hierarchical Fuzzy Expert System is used to build a prediction model based on these critical success factors. The developed research/model benefits both researcher and practitioners to predict accurate company performance.

CHAPTER 1. INTRODUCTION

Construction is a diverse, project-based industry (Ozorhon, 2012). The project-based nature of the construction industry makes every project unique (Veshosky, 1998). Moreover, the market structure is extremely fragmented, making it very competitive and difficult for any particular organization to dominate (Kim & Reinschmidt, 2012). The unique nature of concerns and challenges often render the generalizable decision rules and frameworks for organizational phenomena unusable (Pinto & Covin, 1989). Financial and tangible assets gained are often translated to organization success. In a review of project success factors conducted, it is has been noted that project success was considered only as a subject of implementation in the 1980s (Müller, 2012).

The approach towards the subject has evolved over the years. It is now extended from inception to closing out of a project. Today, the literature in this field spans the entire product life cycle from product success to business success. This change has led to a shift in emphasis from project success to organizational success. The need to examine architectural/engineering/construction (A/E/C) organizations and the factors that impact the performance of organizations is now necessary to compete in an ever-changing marketplace (Liu, Wang, Skibniewski, He, & Zhang, 2014).

1.1 Scope

Organizations have been trying to increase their efficiency and improve their performance in order to achieve their goals. Organizational success is determined by various factors that impact organizational performance. Uncertainty and uniqueness of projects are inherent characteristics of this industry, making it a conglomeration of unpredictable variables. Furthermore, the lack of a performance measurement for the construction industry makes it difficult to evaluate these variables. Hence, developing an effective construction performance assessment model has been very difficult (Rathore & Elwakil, 2015). The objective of the present research is to identify and study the success factors and to develop performance prediction model(s) for construction organizations. The potential success factors are collected from the literature and shortlisted based on construction expert opinions. A questionnaire is prepared and sent to evaluate the impact and implementation of these potential success factors on organizational performance. The collected data is analyzed using a Hierarchical Fuzzy Expert System (HFES) modelling approach to build a prediction model. The developed research/model benefits both researcher and practitioners to predict accurate company performance.

1.2 Significance

Globalized competition and customer needs forced construction companies to assess their performance beyond the financial measures, that is, profitability; turnover, etc (Isik, Arditi, Dikmen, & Birgonul, 2010). Profit and success are considered the main drivers of any organization. Achieving success depends on many factors which have direct effect on the performance of organizations. Most of construction organizational success factors are qualitative in nature rather than quantitative. Thus making it important to determine these success factors, which can then be used later to predict and improve organizational performance.

Modeling the performance of construction organizations from a financial prospective has been extensively researched; however, modeling the performance considering non-financial aspects has not receive sufficient attention from researchers. The ability to predict construction organization performance will enable practitioners to identify weak points, which will lead to search solutions to improve efficiency, which will ultimately increase profits and success (Rathore & Elwakil, 2015).

1.3 Research Question

What factors impact an organization's performance in the construction industry? Develop a comprehensive prediction model based on the non-financial and financial factors that impact an organization's performance.

1.4 Assumptions

The assumptions for this study include:

- The participants of study are experts within the construction industry. By expert, the author assumes that participants have sufficient experience in the construction industry.
- The responses provided by the participants have been made with sound judgement. The ratings provided are on scale of five and they understand that rating of one stands for minimum impact and five stands for maximum impact.

1.5 Limitations

The limitations for this study include:

- The framework for performance assessment model will be based on data responses collected from the experts in industry. The interpretation of questions may vary from individual to individual.
- The participants of survey that form the sample for data collection are not from the same organization or in the same functional role. Hence, the perspectives of individuals will vary from one functional role to another.

- The survey will be conducted for organizations listed in the Engineering News-Record for the top 400 U.S. contractor and the top 500 U.S. design firms. Hence, the impact of certain factors may be on extremes or may not even be included in the shortlisted factors.

1.6 Delimitations

The delimitations for this study include:

- The critical success factors are shortlisted from the existing literature. Out of the eighteen shortlisted factors, only seven parameters are used to develop the overall performance assessment model for construction organizations. Many sub-factors have not been included.

- Due to scarcity of time the data has not been classified as per the type of contracts executed by construction organization i.e. Engineering Procurement Construction (EPC), Design Build (DB), General Contractor (GC), etc. is not considered for this study.

- Most companies listed in the ENR Top 400 Contractors and Top 500 Design firms are not publicly listed. This constraint made it impossible to include financial ratios in the model. However, based on the publicly available revenue of companies, annual growth rate, three year Cumulative Annual Growth Rate (CAGR), revenue from various segments of industry and market diversification entropy have been included.

- The qualitative data collected is based on the opinions of expert. Quantitative data such as the growth rate, revenue per employee, number of full time employees and total years of business for organizations has been collected from the publicly available data sources such as ENR reports, company websites and PrivCo. These are included in model to evaluate the combined impact on the output.

1.7 Definitions

In the broader context of thesis writing, the researcher defines the following terms:

Organization: A social unit of people that is structured and managed to meet a need or to pursue collective goals. All organizations have a management structure that determines relationships between the different activities and the members, and subdivides and assigns roles, responsibilities, and authority to carry out different tasks.

ISO 22301:2013 defines organization as person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objective.

Organization goals: The overall objectives, purpose and mission of a business that have been established by its management and communicated to its employees. The organizational goals of a company typically focus on its long range intentions for operating and its overall business philosophy that can provide useful guidance for employees seeking to please their managers.

Performance: The accomplishment of a given task measured against preset known standards of accuracy, completeness, cost, and speed. An analysis of a company's performance as compared to goals and objectives.

ISO 22301:2013 defines Performance as measurable result. It further states that," Performance can relate to the management of activities, processes, products, (including services), systems or organizations."

1.8 Summary

This chapter provided the scope, significance, research question, assumptions, limitations, delimitations, definitions, and other background information for the research project. The next chapter provides a review of the literature relevant to the factors affecting organizational performance, existing performance metrics and their limitations.

CHAPTER 2. REVIEW OF RELEVANT LITERATURE

This chapter provides a review of literature relevant to the the factors that impact organizational performance. This chapter includes a background on the existing performance metric systems.

2.1 Critical Success Factors

Determining factors for project success or failure has been of keen interest to both academicians and industry professionals alike. Most of the factors identified have been focused on project execution rather than the organizational success. Cooke-Davies (2002) has mentioned in his work that although project management literature does not illustrate much on the corporate success, both direct and indirect link exists. Organization effectiveness depends upon successful management of its projects (Pinto & Covin, 1989). Project success brings about a beneficial change to the organization and vice-versa (Cooke-Davies, 2002). Similarly, any improvement in the organizations structure will improve the chances of project success. Project success is influenced by several critical success factors, for example, top management support, communication, sufficient resources, etc. are derivatives of organizations. Further to this, the study recognizes important factors that link project success and corporate success. These factors are categorized in five areas, which are, general corporate strategy, business operations, research and development, IT/IS development and Facilities management. The paper stresses that every factor deals with people, as they are the ones who execute the project. Thus, it is necessary to include the influence of people in organizations. Pinto and Covin (1989) and Müller (2012) have discussed that project success is dependent on the interaction of individuals, project teams and organizational success.

Chinowsky and Meredith (2000) proposed the concept of seven guiding principles of strategic management for construction industry. These include vision, mission, goals, core competencies, and knowledge resources, education, finance, markets and competition (Chinowsky and Meredith, 2000). Knowledge and information are now considered as critical factors that influence a companys lifespan. They are rated higher than land, capital or labor (Bontis & Dragonetti, 1999). A good knowledge data base will allow organizations to leverage against their competitors in future and thus giving organizations a competitive edge (Arthur, 1994). Unfortunately, knowledge being an intangible asset is difficult to measure and hence often forgotten in the process (Bontis & Dragonetti, 1999).

Organizations are conceptualized as the product of though and action of [their] members (Sims, H. P., & Gioia, 1986) or as Weick (1987) stated the body of thought by organizational thinkers (Nicolini & Meznar, 1995). Human elements are the assets of organizations that are capable of learning, evolving, innovating and creatively propelling the growth of an organization, which is essential for long-run survival of the organization. It has been noted that majority of Human Resource Accounting (HRA) techniques have been designed for industries like accounting firms, banks, insurance companies and financial service firms, where human resources represent a substantial share of the organization value (Bontis & Dragonetti, 1999). However, construction organizations lack such initiatives that are designed to evaluate employee performance, satisfaction and compensation. Factors such as organizations employee culture and engagement are important aspects for an organization. Another important factor are the feedback systems, as they are extremely crucial for implementation of metric system and evaluating performance of organization. Feedback evaluation is one of the critical success factors that aid in analyzing and improving organization performance (Hauser & Katz, 1998).

Earliest seminal works in field of economics by Viner (1931) on long run average cost cycles, that show that economies of scale help organizations to grow efficiently up to a certain critical production level. Expansion of firm that results in reduced cost is called economy of scale. There are two types of economies of scale- internal and external. Internal economies of scale in are long term phenomena achieved by appropriate adjustment of scale of operations to the successive output (Viner, 1931). Technical economies allows organizations to capitalize on the processes and assets developed. For example, a company owning its own fleet of machinery. Pecuniary or purchasing economies allows companies to purchase raw material in bulk and gain purchasing discounts. Companies save across all their plants, departments, divisions, or subsidiaries by utilizing central administrative and management cost by turning administrative department in to shared services center. Large firms benefit from established credit lines. The risk bearing economies can be achieved by large firms as they can afford to take higher risk and take up high risk projects. However they can also suffer from diseconomy of scale, that is, when production increases beyond critical level, it results in diseconomy of scale.

Firm size is one of the factors that can impact an organizations growth. If the firm is too big the management communication can be inefficient due to poor communication and coordination problems. This often leads to low morale in employees. Factors such as morale of employee are intangible and hence, difficult to account for in an organizations growth by just looking at financial statements. Large firms also experience inefficiencies due to Principle-agent problem. Viner (1931) also pointed out that the internal economy of scale is independent to external economy of scale. External economy of scale refers to the positive developments or increase in output generated by the industry as a whole. Similar to internal pecuniary economy of scale, external pecuniary economy of scale also benefits organizations when there is an increase in number of suppliers and they offer more competitive prices. Challenging Viners theory of impact of firm size and economies of scale on the organization performance, Simon and Bonini proposed a stochastic mechanism using Gibrats law for firm growth and the skewed distribution of firm sizes (Simon & Bonini, 1958). The results show that the distribution of percentage of change in the size of firms in a given size class is the same for firms in all size classes. Thus, the expected rate of growth is independent of current size of a firm.

2.2 Existing Performance Metrics

Benchmarking has been defined as a continuous, systematic process for evaluating the products, services, and work processes of organizations that are recognized as representing best practices for purpose of organization improvement (Spendolini, 1992). A company is a complex structure, comprising of various interconnected components that influence its performance (Tang & Ogunlana, 2003). Performance prediction of construction organizations enables identification of the weak points in order to improvise processes and to increase profits (T. Zayed, Elwakil, & Ammar, 2012). The attention of organizations is usually focused on improving the efficiency of its tangible assets as they can be measured and evaluated (Hauser & Katz, 1998). In the process, the organizations often do not consider the invisible and intangible assets that impact the overall performance. A good metric system empowers an organization (Hauser & Katz, 1998). In a recent study and analysis of a case study by Gustavsson (2012), a need for new collaborative project practice development and organizational change has been discussed. Company performance is usually assessed by evaluation of measurable characteristics of performance indicators (Bititci & Muir, 1997). At the same time, it is important to understand that the productivity or output in the construction industry is not homogeneous, that is, outputs cannot be measured in cubic meter. Given the diverse nature of construction industry, it is impossible to aggregate all types of outputs and measure them with one physical measurement unit. It is important to understand the heterogeneous results and develop ways to analyze them (Vogl & Abdel-wahab, 2015).

The existing literature shows that numerous models were developed to measure performance by using critical success factors, performance measures, and indicators. Academics have a tendency to characterize projects as similar entities; thus these studies have been done looking at the broader picture rather than for a particular case (Pinto & Covin, 1989). These studies mostly address metric requirements for the manufacturing industries rather than construction. It is important to note that the product life in the manufacturing industry goes through a standard process. The performance is usually measured in per unit cost. The repetitive process makes it possible to standardize the process and improve the overall performance. The project management studies have been shifting focus to organizational strategies and operations. World manufacturers are now competing on key success factors other than price/cost. Unarguably, the characteristics and properties of goals and challenges may be similar. However, too often academics have generalized decision rules for organizational phenomena, while practitioners have been stressing the unique nature of their concern (Pinto & Covin, 1989). The closest initiative to measure construction performance was based on the total quality management (Fisher, Miertschin, & Pollock Jr., 1995).

One of the earliest measurement instruments developed to measure the project performance was proposed by Pinto and Slevin. The Project Implementation Profile (PIP) allows assessment of an organizations ability to carry a project through its full implementation (Pinto & Mantel, 1990). The PIP was a support tool to enable managers to assess the status of their project by seeking answers to questions related to 10 critical success factors identified by Pinto and Slevin (1987). The process required participants to give responses on a 5-point Likert scale. These responses were used to assess success or failure in terms of time schedule, budget overrun, quality of work, client satisfaction and utility of final project. It is important to note that the tool was developed focused more on project success rather than organization success. It is undeniable that the factors also concern the organization, for example, the resources and budget also fall under the organization performance. However, the tool does not take cognizance of these factors and is not effective enough to understand the overall performance of the construction organization.

In 1992, members of Houston Business Roundtable (HBR) embarked on the journey of establishing performance metrics. This process included sending out a survey to member companies of HBR to determine four main preliminary tasks: determine the interest of HBR companies in a metric system; identify activities that should be measured; how to measure activities; collect information and analyze information. After confirming a 90% interest and willingness from HBR member, the HBR members decided on 10 activities that were selected for benchmarking. The 10 factors were costs (actual vs authorized), schedule (actual vs estimated), scope changes, reengineering work, construction labor (actual vs estimated), worker hours per drawing, project cost distribution, field defects and percent of rejected welds (Fisher et al., 1995).

Studies conducted in the construction industry have laid more emphasis on the measurement of project performance rather than company performance (Isik et al., 2010). Bontis and Dragonetti (1999) proposed the Balanced ScoreCard (BSC). The framework placed emphasis on qualitative measures at the organizational level and advocated the balance between measures of financial and non-financial success. Another example of performance measurement and management framework is the Performance Prism. The first part of this framework encourages assessing stakeholder satisfaction and assessing the needs of the stakeholder. The second part is to understand the needs of organization (i.e., the reciprocal relationships) as well as on how to align strategies, processes and capabilities (Neely, Adams, & Crowe, 2001). The Prism focuses on significant measures and connects the performance practices within the organization. These frameworks are more than a decade old. Hence, in order to keep up with the ever changing markets, many new studies are being carried out. Performance measurement has always been a challenge in construction industry (Nasir et al., 2012). The construction industry has not seen much improvement in productivity and performance measurement as in manufacturing sector (Harrison, 2007). Industry groups in several different countries have initiated benchmarking programs focused mainly on construction performance measures (Costa, Formoso, Kagioglou, Alarcón, & Caldas, 2006). Earliest concepts of bench marking systems in construction industry were introduced in 1990s and were initiated by countries like the United States of America, the United Kingdom (UK), Chile, Japan, and Brazil. In 1993, the Construction Industry Institute introduced the first benchmarking system in the public sector of the construction industry. This was followed by the Construction Excellence Program launched by the Construction Best Practice Program (CBPP) and Key Performance Indicators (KPIs) program launched by the UK Best Practice Program in 1988 (Nasir et al., 2012). In 2008, the Construction Sector Council, a Canada based organization, launched a program to measure and benchmark project performance in the Canadian construction industry. The metrics developed benchmarks to measure: project cost, time, safety and quality performance; labor productivity; rework; project conditions and management practices related to health. The goal of the program was to develop benchmarks to assess the labor productivity and project performance (Nasir et al., 2012). Again, the study was based on the project success factors.

Costa et al. (2006) has summarized various benchmarking systems employed by construction industry from four different countries (i.e., Brazil, Chile, the UK and the US). The benchmarking initiatives are 1. Key Performance Indicators in the UK; 2. National Benchmarking System for Chilean Construction Industry (NBS-Chile); 3. CII benchmarking system and metric in US; and 4. The performance measurement in for benchmarking in Brazilian Construction Industry. These programs have generated recommendations like: Classification of performance measures; establishing frameworks that allow performance to performance management; 3. developing collaborative learning processes; inventing new measures; and developing framework for performance assessment.

Another framework proposed by Canadian Construction Innovation Council (CCIC) evolved from the project success factors to a framework that encompasses factors that impact the organization functioning. The metrics developed by the CCIC would be relevant to the project and organization level, and also allow indication and assessment of performance at the organization level. This framework included factors that were categorized into seven main performance categories, that is, costs (estimated, actual and predicted), time (estimated, actual and predicted), quality (levels of client satisfaction), safety (incidents and lost time), innovation (procurement, management, technology), and sustainability (design and construction). The major drawback of this framework is that it required accurate data for a large number of factors and the analysis followed was even more complex (Nasir et al., 2012). Organizations that focus on satisfying the customers with greater efficiency and effectiveness have an edge over their competitors (Neely, Gregory, & Platts, 1995). Studies have shown that practitioners have been able to determine that improving communication has a major impact on construction practice. It allows better customer engagement, leading to better performance of organizations. Neely et al. (1995) stresses the importance of metrics associated with quality, time, cost and flexibility, thus relating performance of organizations with project success.

Attempts have also been made to understand the relationship between the internal and external factors affecting organizational performance. Empirical studies carried on the construction market structure show that the construction industry being highly fragmented makes it very competitive (Kim & Reinschmidt, 2012). Studies have been carried out to identify relationship between market fragmentation and organizational diversification (Kim & Reinschmidt, 2012). By analyzing return on mean equity, Pandya and Rao (1998) concluded that specialized or less diversified firms face more volatility in profitability than more diversified firms. Choi and Russell (2005) used 12 years data of publicly traded companies to identify any relation between diversification and profitability. However, no significant difference in profitability were found in companies categorized by different diversification level.

In a previous study by (T. Zayed et al., 2012), nine critical success factors (CSFs) were defined as the most significant to develop a prediction model for organizational performance. The Artificial Neural Network (ANN) model was used to assess the most significant success factors, as ANN provides the contributing weight of each factor after the completion of the training process. Another study developed a fuzzy logic model with the same data aiming to develop the best fit model for the performance prediction (Rathore & Elwakil, 2015).

2.3 Modelling techniques adopted- Fuzzy Approach

Lotfi Zadeh introduced fuzzy logic as a powerful modeling technique that is can be used to understating the uncertainty and qualitative aspects of human nature (Zadeh, 1965). Fuzzy techniques have been widely utilized in several studies over the past decade. It has the ability to virtually connect humans to computers through analyzing linguistic inputs to stem numerical outputs (Chan, Chan, & Yeung, 2009). Traditionally, a set of inputs has sharp and crisp boundaries, where elements are either in or out of a set, and ranking of a membership of a variable is zero or one (Nguyen, 1985). However, in the real world, information is mainly ambiguous and incomplete. That is when fuzzy logic is applicable as elements are allowed to have partial memberships ranging from zero to one (i.e., zero is no membership and one is full membership) (Fayek & Oduba, 2005).

T. Zayed et al. (2012), has previously developed prediction models for performance of construction organizations using the Artificial Neural Network model and regression. A total of 18 factors were identified from the literature review. Based on the responses received from industry experts (5-point Likert scale was used), these factors were evaluated and allotted ranks using ANN training (i.e. ranking the factors to determine the relative importance of each variable and the highest impact on the model). Analysis of weights of the trained neural network are used to derive the contribution percentages. The higher the value implies that the variable contribution to classification/prediction is also high. Based on the ANN rankings, nine factors with highest contribution factor were shortlisted from the pool of 18 factors Neuroshell software package was used to develop and train the ANN model. Similarly, MINITAB software is used to build a regression model for construction organizations performance using the selected CSFs.

One of the many advantages of theoretic properties of ANN is the ability to distinguish unspecified relations such as nonlinear effects and/or interactions. However, this advantage comes at the cost of minimized interpret-ability of the model output. The black box quality of an ANN model makes it next to impossible to gain insight into a problem based on an ANN model. Regression technique allows the user to sequentially remove possible explanatory variables that do not contribute to the fit of the model (Sargent, 2001). Regression techniques permit hypothesis testing concerning both the uni-variate and multivariate association amongst each explanatory variable and the outcome of interest. However, it fails to recognize or identify the highly nonlinear factors, or correlation among variables Sargent (2001). Human reasoning being more approximate than precise in nature often makes it difficult to measure and determine the measure of factors affecting a particular cause.

2.4 Challenges and Limitations of Existing Metrics

The process to develop a successful performance prediction model is a very long and tedious task. It takes analysis of a large number of factors from a broad strata of projects. The data requirements are immense. Also, the project values, life-cycle, location, etc. are the variables that need to be accounted for. The time taken to develop the program, identify potential participants, introduce the concept, obtain feedback, revise parameters, re-evaluate can be extremely long. Further to that, it is a challenge to convince firms to provide data for the on-going projects and data on any changes that may be observed after the suggested actions. Once a benchmark has been developed, it becomes a significant strategic asset. CII took almost eight years to derive a functional benchmarking model with considerable number of projects to make meaningful assessments at project level (Nasir et al., 2012). Despite the awareness and importance performance measurement data, companies or knowledge bodies have not been able to establish data banks (Costa et al., 2006). Existing empirical studies only focus on few factors and attempt to establish a relationship. These factors can be internal, that is, with in organization and external related to market conditions. Previous studies have focused on individual or combination of few factors. Due to the limited scope the whole system has not been evaluated. Thus making it necessary to understand and identify the underlying relationship between the factors amongst categories and the across different categories that impact an organizations performance.

The data from companies vary as the companies that execute small projects only form a fraction of the total industrys turnover. Only large organizations are able to afford executing projects with a very small profit margin, as they have in house capabilities, established processes, established lines of credit and qualify for large projects. However, it is important to note that small organizations barely manage to stay afloat. It will thus be necessary to account for the organization size while developing a prediction model. Alternatively, different prediction models need to be developed depending on the organization size, specialty contractors, types of contracts undertaken, for example, Engineering Procurement and Construction (EPC), Construction Management at Risk (CMR), Architectural and Design firms, General Contractor, etc.

2.5 Summary

This chapter provided a review of the literature relevant to the critical success factors that impact organizational performance, existing metric systems and the challenges that are associated with the existing metrics. The next chapter provides the framework and methodology to be used in the research project.

CHAPTER 3. FRAMEWORK AND METHODOLOGY

This chapter outlines the intent of research, methodology and specifics related to data collection. The author will first discuss the purpose of research and then explain the methodology in detail along with reasons for the chosen methodology and conclude with review and summation.

3.1 Framework

The existing literature shows that numerous models were developed to measure performance by using critical success factors, performance measures, and indicators. However, they mostly address metric requirements for the manufacturing industries rather than construction. Studies conducted in the construction industry have placed more emphasis on the measurement of project performance rather than company performance (Isik et al., 2010). The attention of organizations is usually focused on improving the efficiency of its tangible assets as they can be measured and evaluated (Hauser & Katz, 1998). In the process, the organizations often do not consider the invisible and intangible assets that impact the overall performance. A good metric system empowers the organization (Hauser & Katz, 1998).

3.2 Methodology

The methodology for this research are summarized step-wise as below:

- A literature review is conducted to identify the factors that impact performance of the construction organizations. Factors shortlisted from the literature review will be analyzed for their impact on performance of the

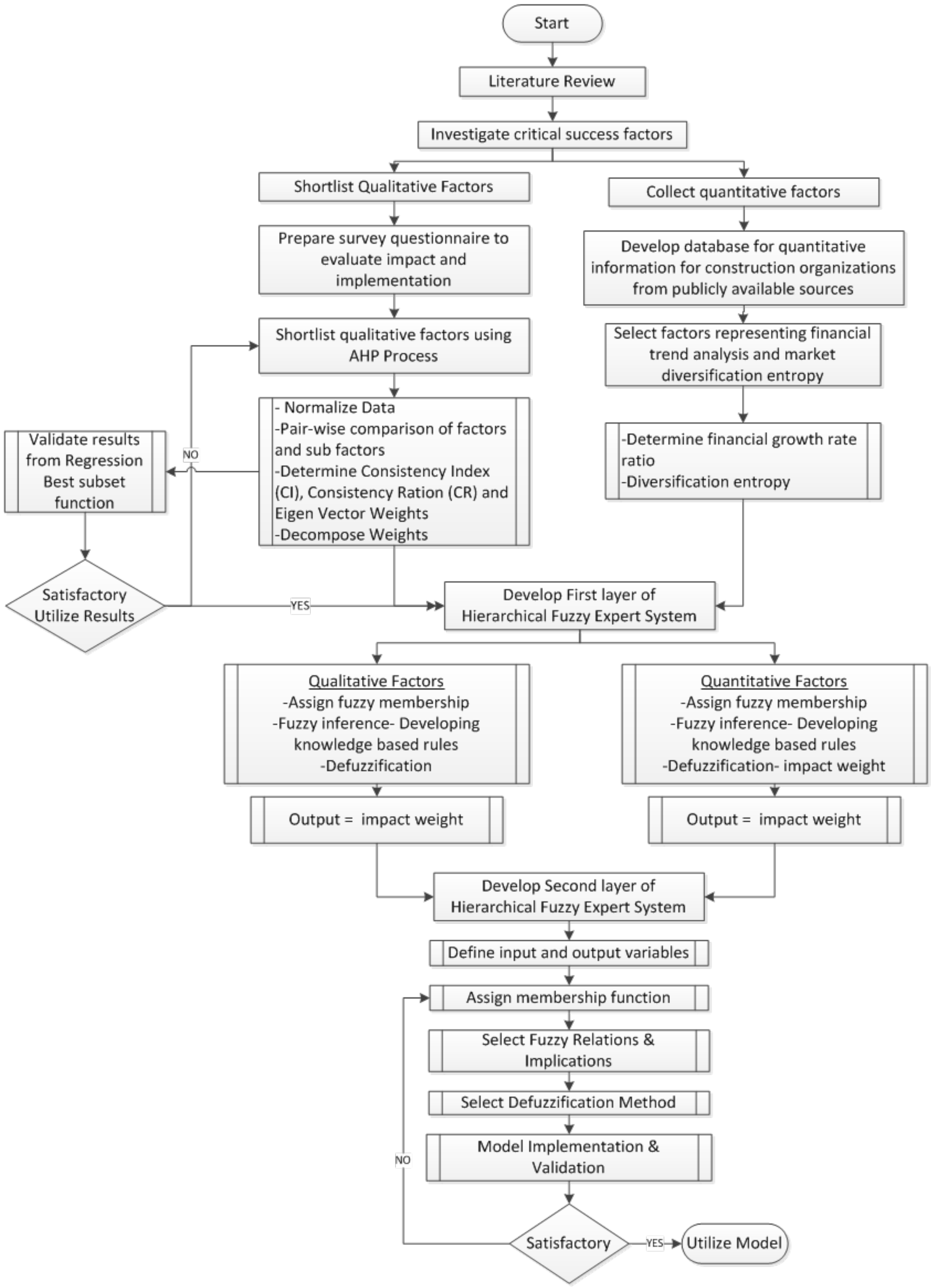

Figure 3.1.: Research Framework

construction organization. These factors are also referred to as Critical Success Factors (CSFs).

- Based on the literature review conducted, factors that have an impact on organizational performance have been shortlisted. The proposed performance assessment model will include both qualitative and quantitative factors. The model is developed in order to determine the overall performance in terms of category of rank. Due to the nature of research question, the researcher has adopted a mixed method- qualitative and quantitative approach. The framework of this research is presented Figure 3.1.

- A questionnaire is designed to evaluate the impact and implementation of the shortlisted non-financial CSFs in their respective organizations. The questionnaire also asks about the participant's total number of experience, the designation held in the current organization and name of the organization, refer Appendix A. The questionnaire is distributed to professionals across the construction industry via in-person interaction, emails and an on-line qualtrics survey.

- Simultaneously, a database for quantitative factors is compiled for all organizations, whose employees participated in the survey. From this data, factors representing financial trend analysis and market diversification of organization are calculated.

- Analytic Hierarchical Process (AHP) is used to shortlist 18 qualitative factors. The results of this process will be validated from the Best Subset Regression function. The subset with highest R_{sq} and adjusted R_{sq} will be used for modelling purpose.

- A performance assessment model for the construction organization is developed using a Hierarchical Fuzzy Expert System. As the number of factors are large and their values are on different scales. It is recommended to use the Hierarchical Fuzzy Expert System (HFES).

- The first layer of HFES is developed by building two sub-models of fuzzy expert system for non-financial (qualitative) factors and financial (quantitative) factors. The input variables are the respective sub-factors and the output is the impact value of the combined effect of sub-factors.

- The output from first layer is used as input for the second layer of fuzzy expert system. The input variables are assigned fuzzy membership and fuzzy relations are established. The defuzzification gives the category of rank of the organization.

- The model will be tested and mathematically validated by Average Validity Percentage (AVP) and Average Invalidity Percentage (AIP) in order to determine the accuracy in assessing the performance of construction organization.

3.3 Study Variables

The study aims at evaluating organizational performance based on both financial and non-financial parameters. Hence, the study variables are categorized in three broad categories, that is, Non-financial parameters, Financial parameters and Market Condition as presented in Figure 3.2

3.4 Independent Variables

This study aims at assessing the qualitative factors with quantitative factors. Independent variables are the input variables that determine the value of output or dependent variable. Based on the literature review, 18 qualitative factors have been shortlisted for non-financial critical success factors, as shown in Figure 3.3. These

Figure 3.2.: Study variables

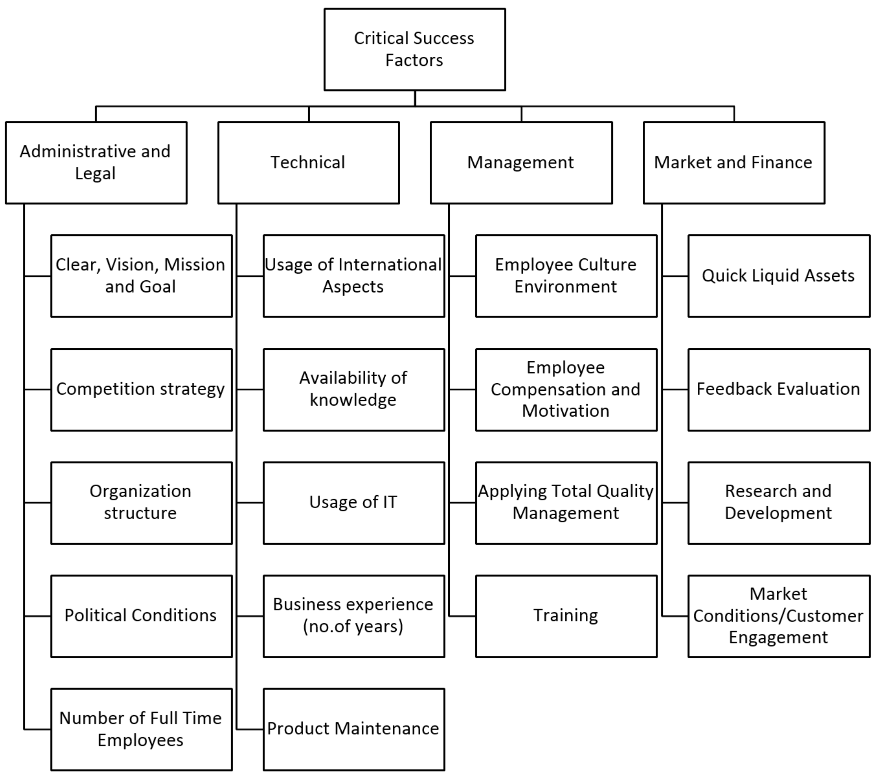

Figure 3.3.: Non-financial critical success factors

factors have previously been investigated in study conducted by Elwakil et al. (2009) and Rathore and Elwakil (2015). The qualitative variables are categorized in four categories, i.e., Administrative and Legal; Technical; Management and Market and Finance as presented in Figure 3.3.

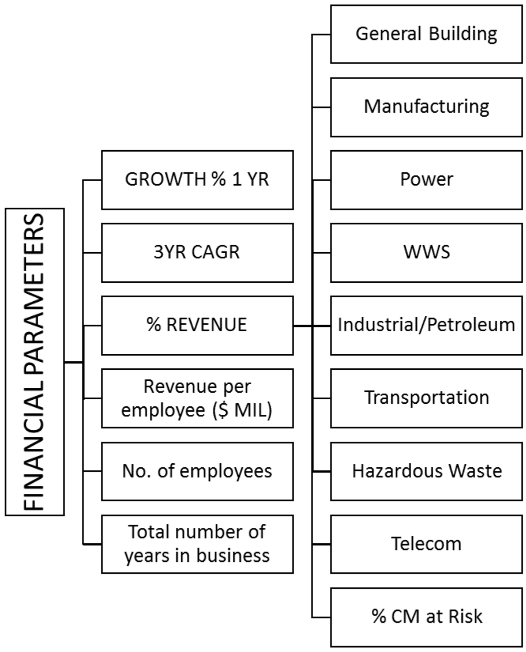

Figure 3.4.: Financial critical success factors

A total of 18 quantitative factors have been identified for the study. It includes financial factors representing organization growth and market diversification. Based on the publicly available financial information factors pertaining to revenue and annual growth are included in the model. A longitudinal database of revenue for organizations for past 5 years was compiled. The factors include annual growth rate in revenue, three year cumulative, percent of different market segment revenue, productivity (revenue/employee), total number of years in business and firm size (number of employees) as presented in Figure 3.4. Figure 3.4 shows the financial factors compiled from the publicly available data. Additionally, the Market Diversification of an organization is measured by Entropy, which is computed as shown in Equation 3.1.

$$Entropy = \sum_{i=1}^{N} ln\frac{1}{p_i} \tag{3.1}$$

Where, p_i= Revenue share of the ith segment in firm total revenue

N= Number of Market segments

3.5 Dependent Variables

The dependent variable is the rank of the organization published by ENR Top 400 Contractors and ENR Top 500 Design Firm Sourcebook 2015 published. The rank is inversely proportional to the revenue of the organization in the year 2015. Higher the revenue earned, smaller is the rank. To maintain confidentiality of the organizations the rank has been categorized into categories, i.e. 1-100, 101-200, 201-300, 301-400, 401-500 and 501 and above. This variable is also the output in model.

3.6 Sample and Population

The study focuses on the organizational performance of construction companies. The proposed model includes the financial factors, hence, the population for this study will be the construction companies listed in ENR Top 400 Contractor and Top 500 Design Firm Sourcebook 2015. Participants from the mentioned companies were recruited through interaction at Purdue University's Building Construction Management Career fair in Spring 2016.

3.7 Survey

The questionnaire had two parts where Part I asked the experts from construction organizations to answer the questions pertaining to their total experience in construction industry, the designation they hold in current organization and the name of the current organization they work for. Part II asked the experts to use a specified five-point Likert scale to rate the impact and implementation of identified success factors on organization performance. The scale was specified from 1 being Very Low to 5 being Very High.

3.8 Data Collection

The data collection procedure included a literature review and identification of potential critical success factors. Eighteen non-financial factors were shortlisted. This was followed by preparation of questionnaire designed to assess the impact and implementation of these factors in construction industry.

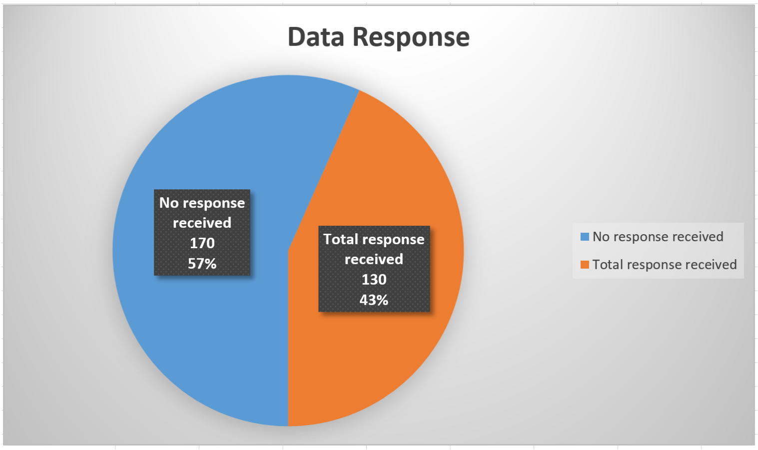

Figure 3.5.: Data response

A total of 300 questionnaires were sent out to organizations. Out of which 130 responses were received, that is a response rate of 43.3%. Approximately 40 responses were incomplete or had missing information about the company they worked for, which made it impossible to link the financial information. Hence, these responses had to be excluded and only 90 responses were used for this study as presented in Figure 3.5 and Figure 3.6. Out the 90 responses, 72 responses were used for training and modelling purposes and 18 responses were kept aside for validation purpose.

Following results were obtained from the responses to survey questionnaire:

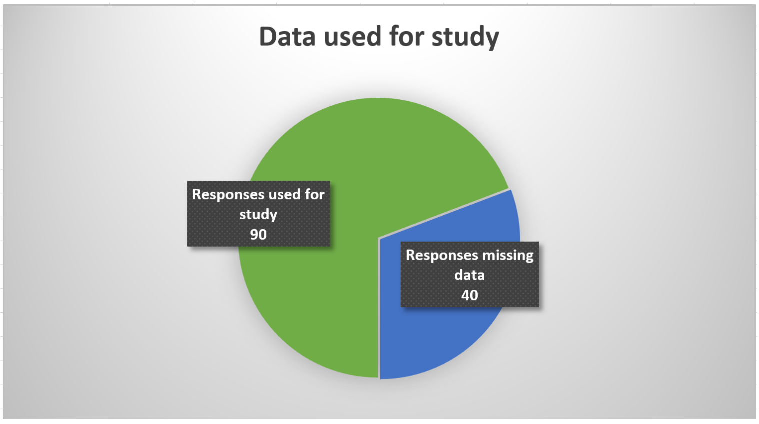

Figure 3.6.: Data used for study

- Survey population characteristics: Based on the responses, it can be seen that the number of the responses received from participants belong to organizations ranked in five rank categories, that is, 1-100 (42 responses), 101-200 (19 responses), 201-300 (8 responses), 301-400 (2 responses) and 401-501 (19 responses), refer figure 3.7. It can be seen in figure 3.8, the responses received have a big cluster of companies in the rank category from 1-200. There are few responses from companies that are ranked in the range between 250-500. The next cluster is the companies that are ranked more than 500.

- Clear Vision, Mission and Goals: Based on the response from participants, it can be seen that the highest rating is given by participants from companies ranked between the range 1 to 100. Most participants have rated the implementation of clear vision, mission and goals in their respective organizations as high, as seen in Figure 3.9. The mean rating is 4.077 and the standard deviation is 0.9625.

- Competitive Strategy: It is observed from the responses that irrespective of the rank of organization, most participants have intended to rate the competitive strategies employed in their organizations as high, as seen in Figure 3.10. The mean rating is 4.043 and the standard deviation is 0.850.

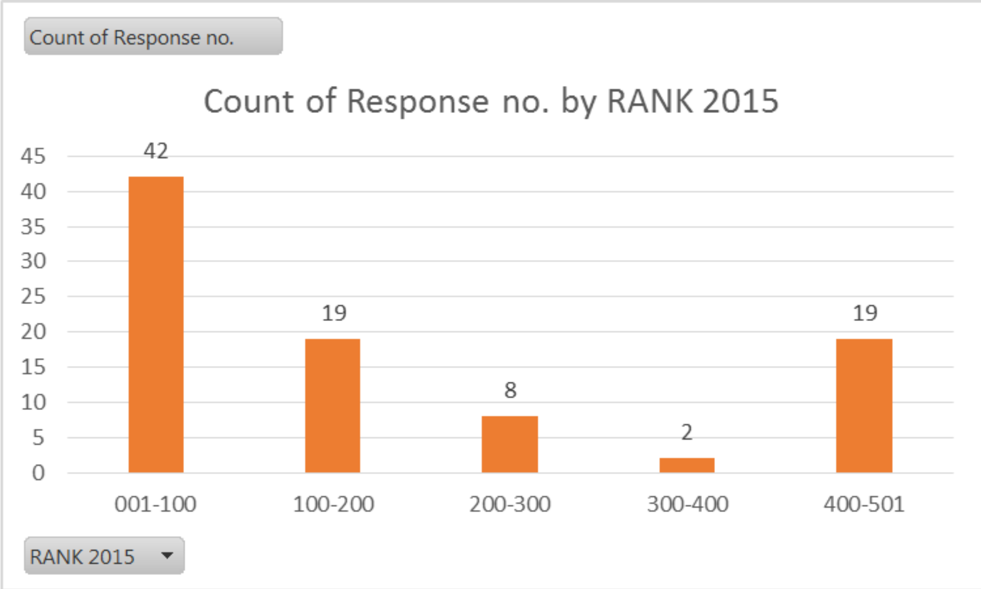

Figure 3.7.: Participant population characteristic

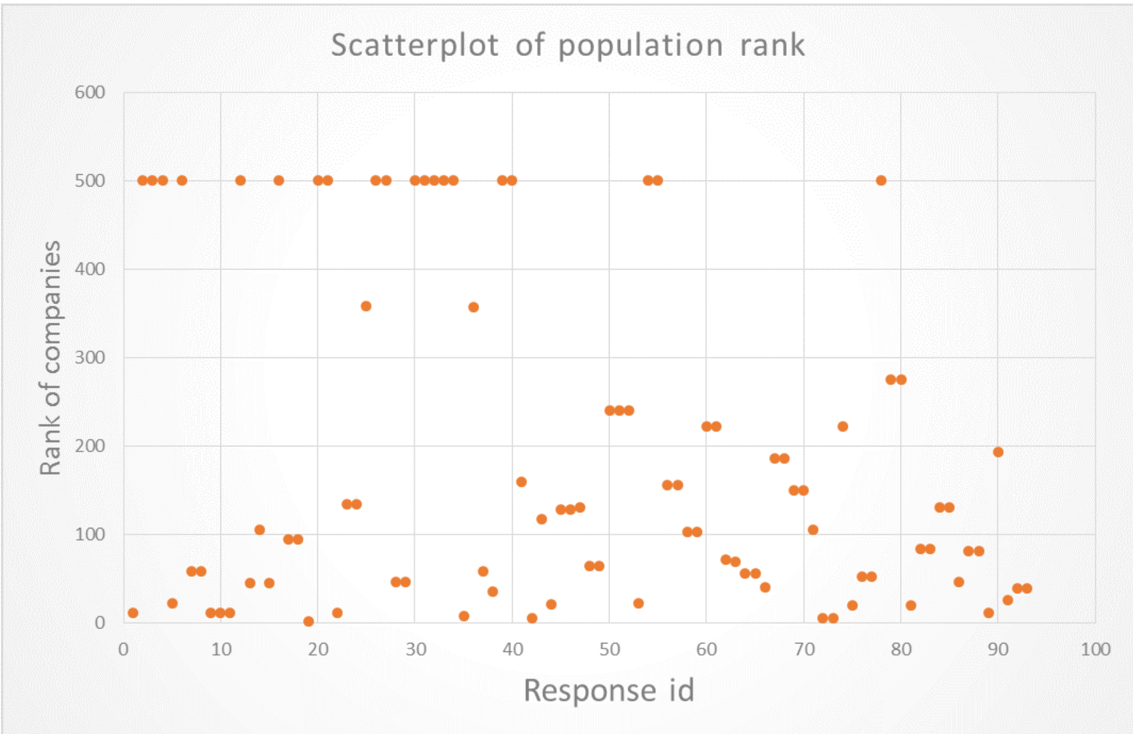

Figure 3.8.: Participant population characteristic

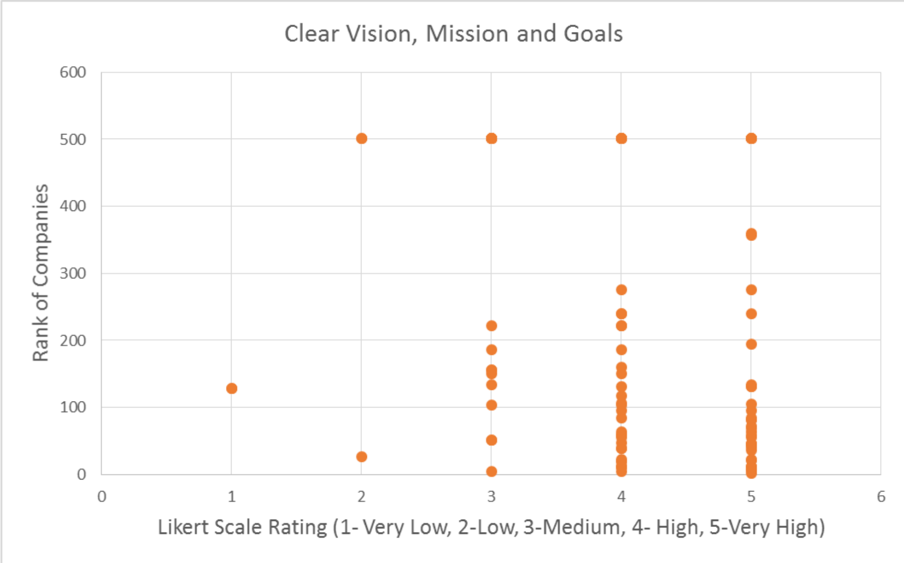

Figure 3.9.: Rating for implementation of Clear, Vision, Mission & Goals vs Rank of organization

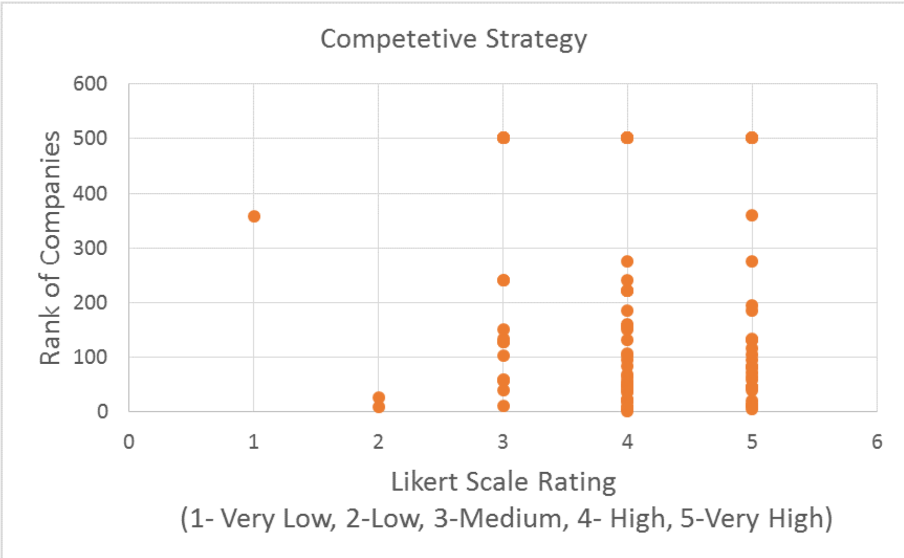

Figure 3.10.: Rating of Competitive Strategy vs Rank of organization

- Organization Structure: The responses for the implementation of organizational structure is evenly distributed between rating of low and very high, as seen in Figure 3.11. The mean rating is 3.828 and the standard deviation is 0.985.

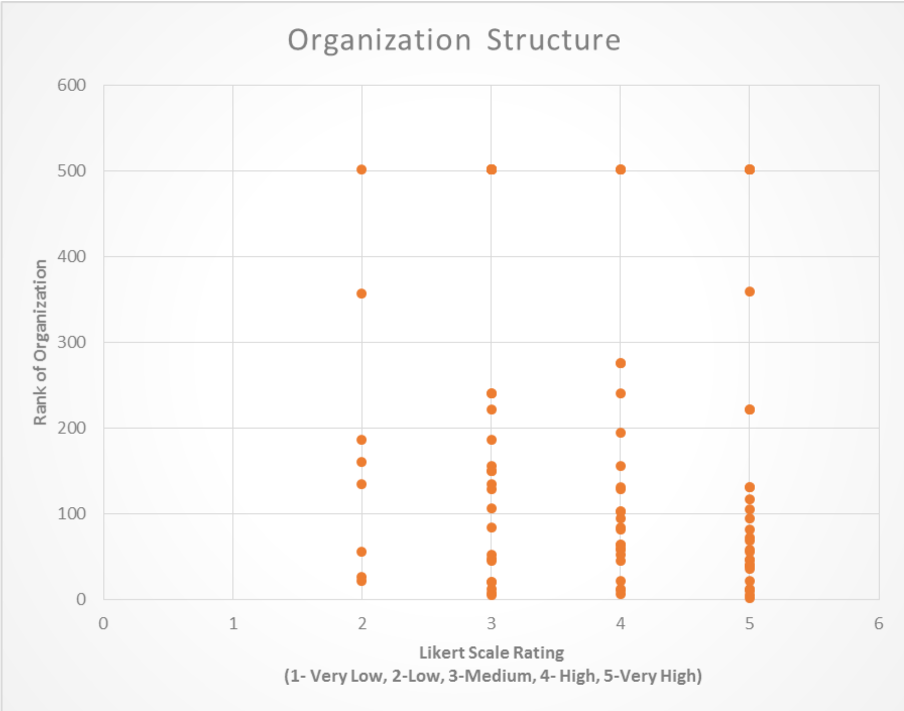

Figure 3.11.: Rating of Organizational Structure vs Rank of organization

- Political Condition: The responses for the implementation of policies pertaining to Political Conditions is evenly distributed around medium, as seen in Figure 3.12. The mean rating is 2.881 and the standard deviation is 1.117. It also implies that the political conditions in the U.S.A. are very conducive for business.

- Number of Full Time Employees: The responses from the participants is evenly distributed around medium rating, as seen in Figure 3.13. Construction industry employees full-time employees as well as contractual labour. It can be inferred from this rating that these organizations sub-contract jobs in projects. For certain specialty jobs, most prime contractors do not self perform. Such jobs are awarded to sub-contractors who specialize in it.

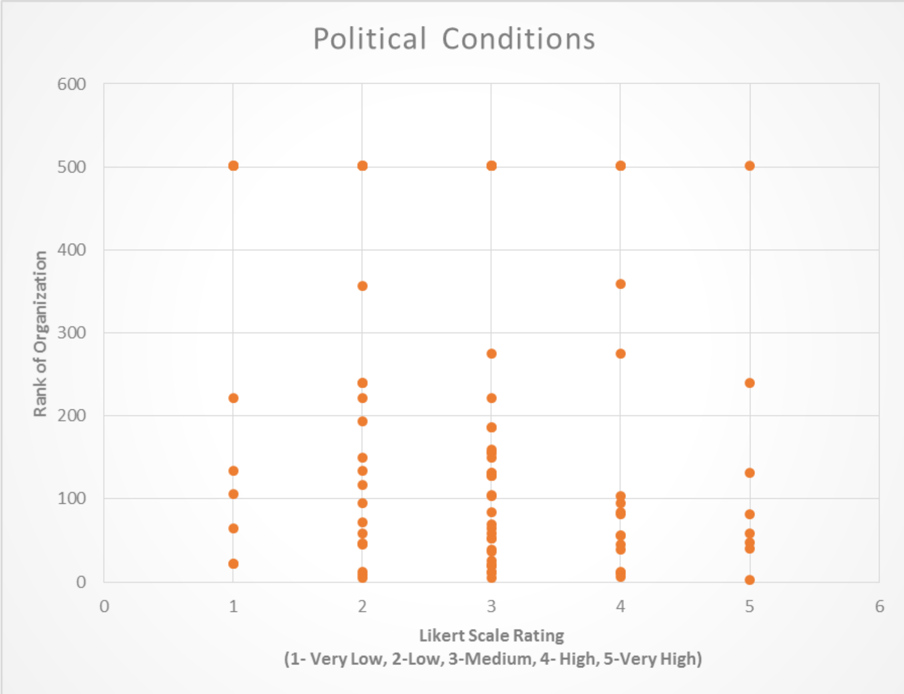

Figure 3.12.: Rating of Political Condition Policies vs Rank of organization

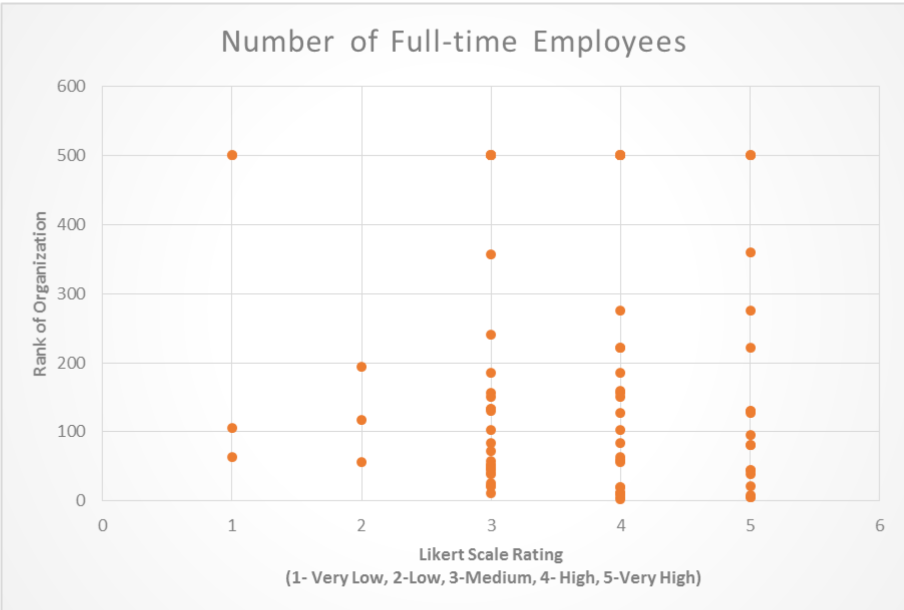

Figure 3.13.: Rating of Number of Full-time Employees vs Rank of organization

Additionally, it helps to control the overhead costs with-in the organizations. The mean rating is 3.659 and the standard deviation is 1.108.

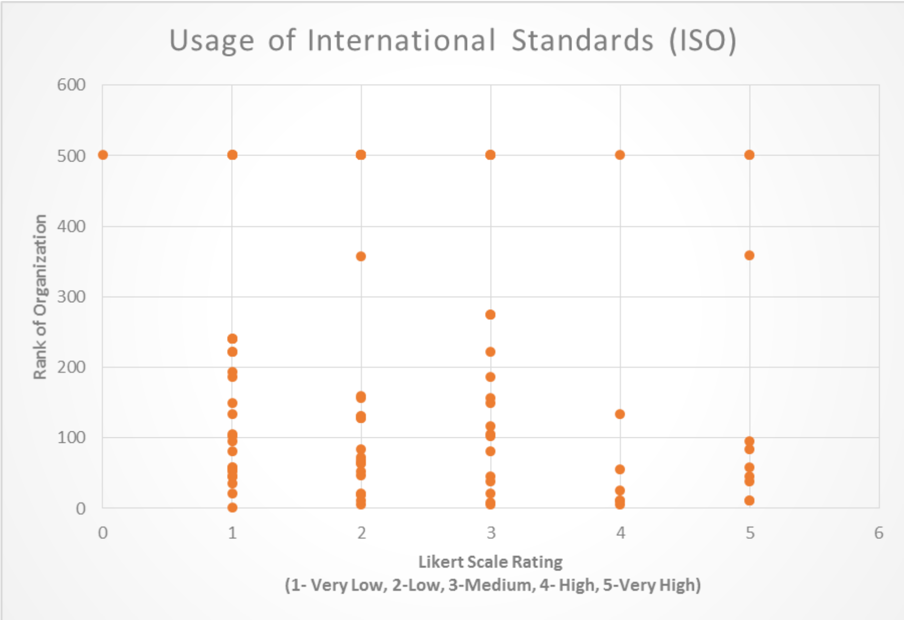

Figure 3.14.: Rating for Usage of International Standards (ISO) vs Rank of organization

- Usage of International Standards (ISO): The responses for implementation of the International Standards in the organizations is mainly spread between low and medium, as seen in Figure 3.14. One of the reasons for such rating is that most organizations work on projects within the U.S.A. and mostly follow American Standards Codes. The mean rating is 2.389 and the standard deviation is 1.313.

- Availability of Knowledge: The responses from participants imply that the experience of professionals, establishing database and learning from previous projects in the organizations is ranked high, as seen in Figure 3.15. The mean rating is 3.967 and the standard deviation is 0.857.

Figure 3.15.: Rating for Availability of Knowledge vs Rank of organization

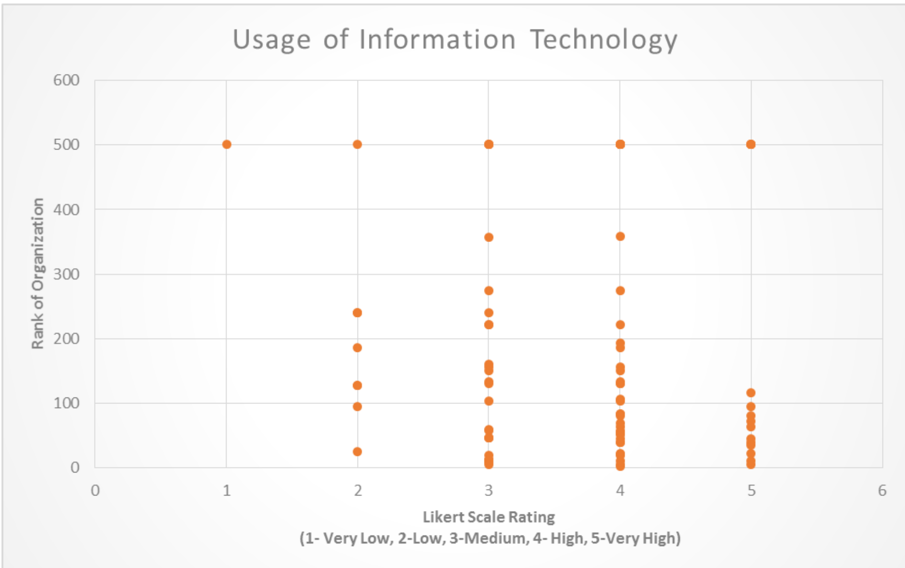

Figure 3.16.: Rating for Usage of Information Technology vs Rank of organization

- Usage if Information Technology(IT): The responses for usage of technology is rated between medium and high,as seen in Figure 3.16. It is also observed that companies ranked between have given rating primarily in high and very high.

Thus, it can be implied that organization with high ranks depend on usage of IT very much. The mean rating is 3.674 and the standard deviation is 0.9037.

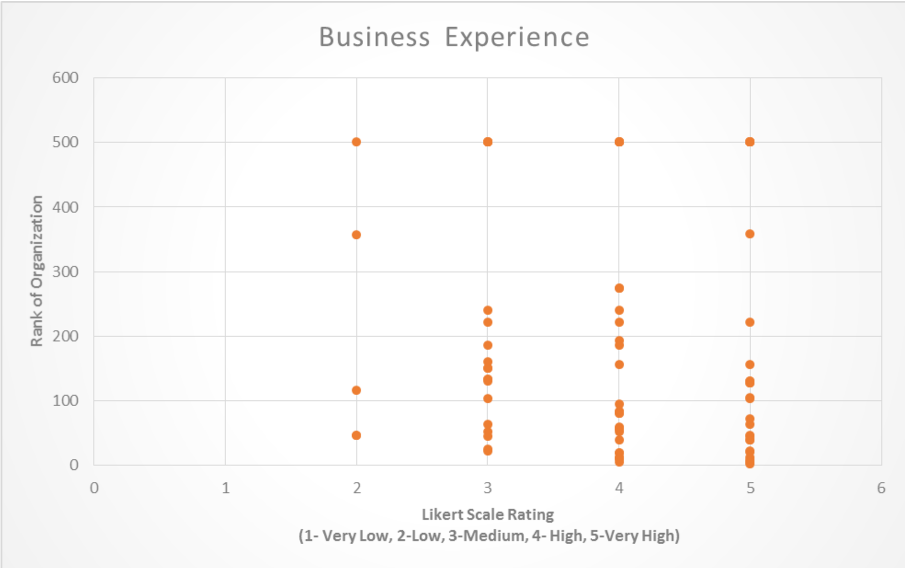

Figure 3.17.: Rating for Business Experience vs Rank of organization

Figure 3.18.: Business Experience (years) vs Rank of organization

- Business Experience: The responses show that participants from companies ranked between rank 1 to 100 have rated business experience of their organization as high and very high. It also means that organizations with high ranks have been in construction organization for a longer number of years. The mean rating is 3.988 and the standard deviation is 0.9062. Further, to compare this response to quantitative value of number of years of business experience, data pertaining to actual number of years of business was collected which is shown in Fig 3.18. It can be seen that most responses have been rated higher. To reduce the bias, the quantitative data was normalized and then converted to 5 point rating for model development.

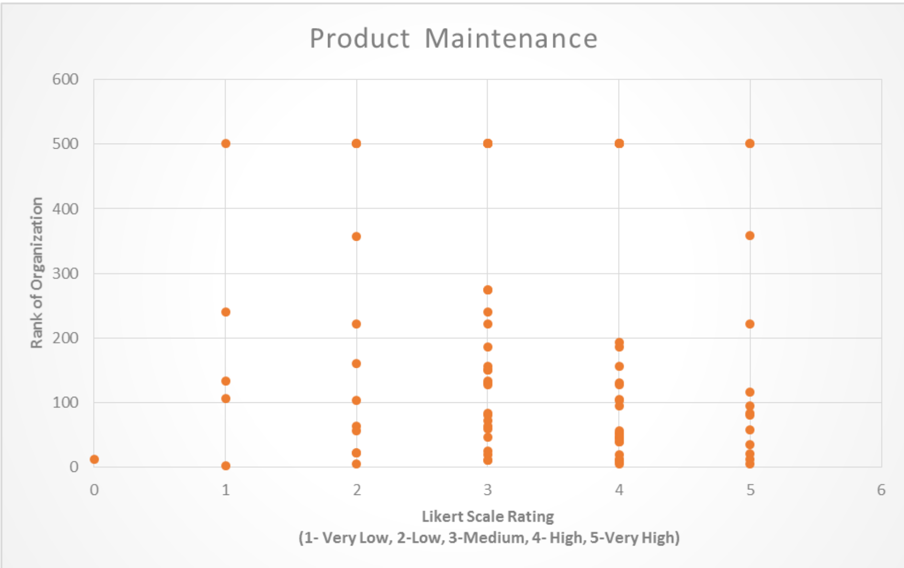

Figure 3.19.: Rating for Product Maintenance vs Rank of organization

- Product Maintenance: The responses for product maintenance, that is services after project completion, has distributed over ratings, as seen in Figure 3.19. Most organizations complete the project and handover the spaces. It is difficult to establish, if there is any co-relation between project maintenance services and organizational rank. The mean rating is 3.340 and the standard deviation is 1.133.

Figure 3.20.: Rating for Employee Culture Environment vs Rank of organization

- Employee Culture Environment: The responses for employee culture environment varies from medium to very high, as shown in Figure 3.20. It can be implied that the most participants have rated the employee culture as high. One of the reasons for such a response could be their presence as company representatives and recruiters at Purdue Building Construction Management Career Fair. The mean rating is 4.175 and the standard deviation is 0.889.

- Employee Compensation and Motivation: The responses for employee culture environment varies from medium to very high, as shown in Figure 3.20. An interesting observation is that the number of participants who rated employee culture as very high are more than those who rated employee compensation. It can be implied that participants prefer a good employee culture environment in organization. However, they are not very happy with the compensation they receive. The mean rating is 3.835 and the standard deviation is 0.859.

- Applying Total Quality Management (TQM): The responses for application of total quality management practices varies from medium to high, as shown in

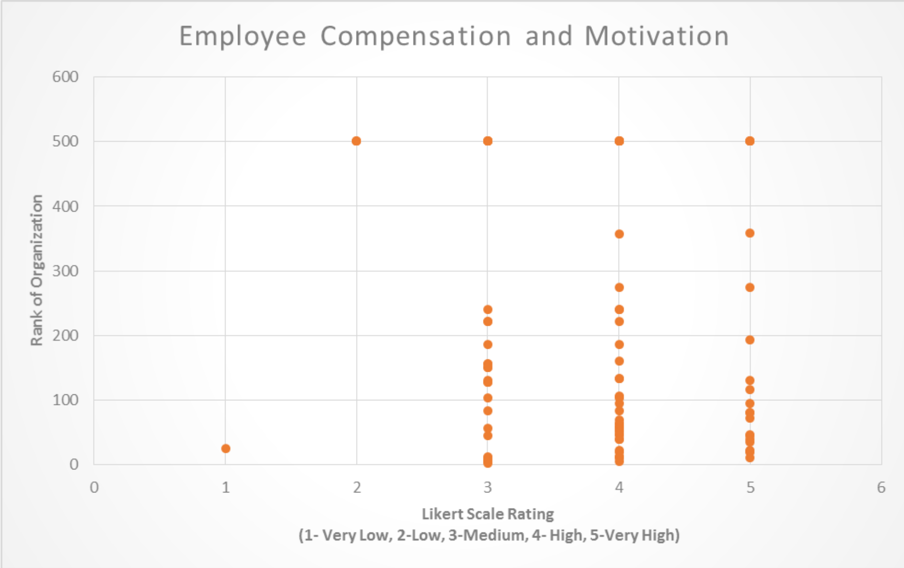

Figure 3.21.: Rating for Employee Compensation Motivation vs Rank of organization

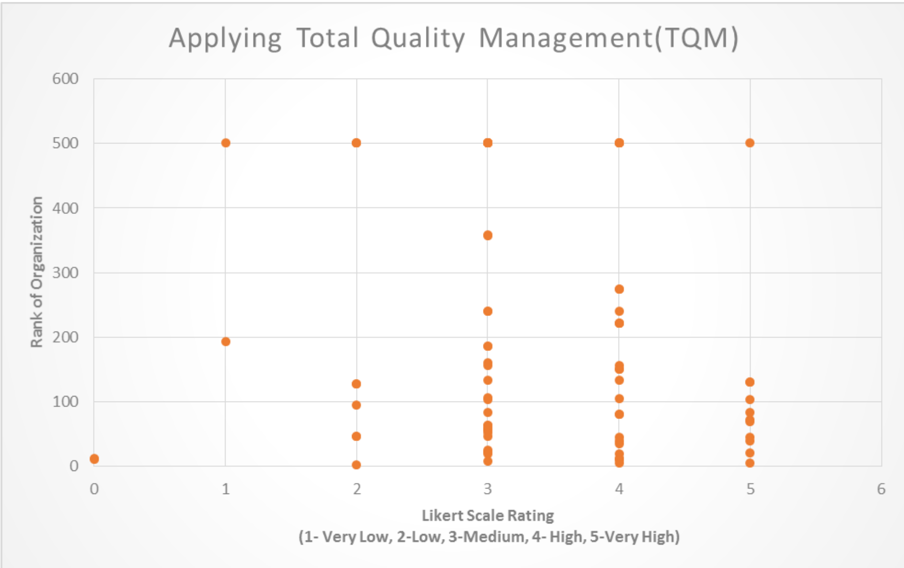

Figure 3.22.: Rating for Total Quality Management(TQM) vs Rank of organization

Figure 3.22. It was observed that most organizations place high emphasis on quality. However, there are some organizations that lack a total quality management system. The mean rating is 3.342 and the standard deviation is 1.064.

Figure 3.23.: Rating for Training for Employees vs Rank of organization

- Training for Employees: The responses for employee training varies from medium to high, as shown in Figure 3.22. Most organizations place high importance on on-job training for their employees. The mean rating is 3.922 and the standard deviation is 0.902.

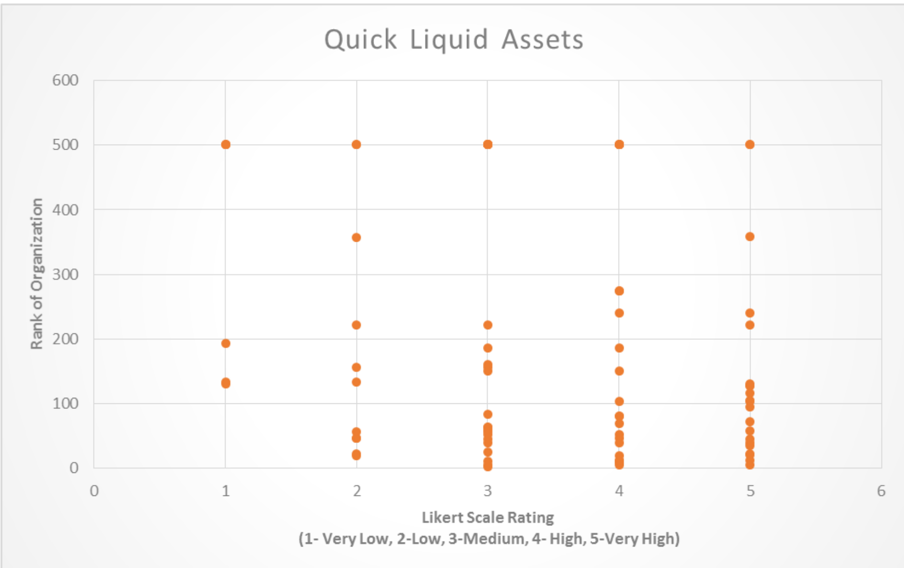

Figure 3.24.: Rating for Quick Liquid Assets vs Rank of organization

- Quick Liquid Assets: Construction industry is a very asset intensive industry. The responses for employee training varies from medium to high, as shown in Figure 3.24. It may also be noted that companies ranked between 1 to 100, have high asset liquidity. It can be implied that these organizations' cash flow cycle is well managed. The mean rating is 3.488 and the standard deviation is 1.195.

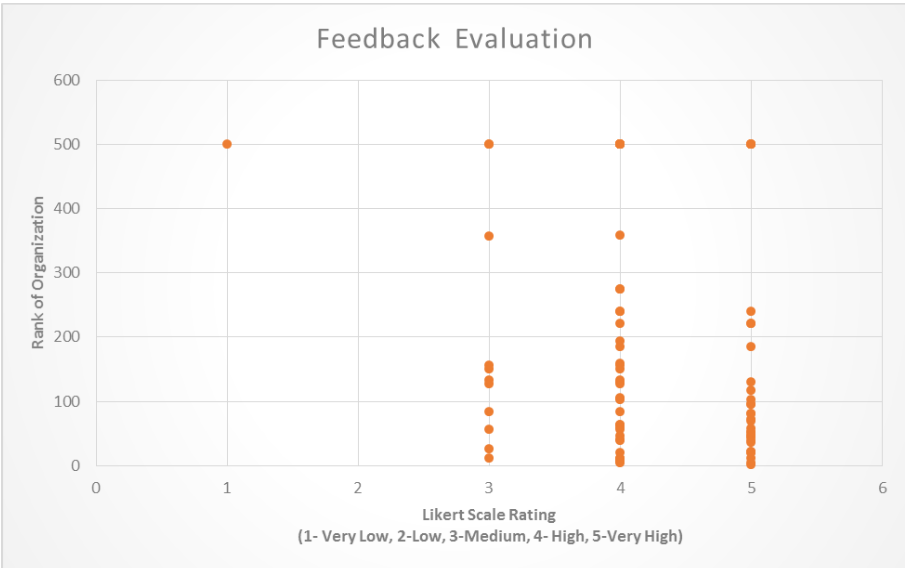

Figure 3.25.: Rating for Feedback vs Rank of organization

- Feedback Evaluation: The responses for feedback evaluation varies from medium to very high, as shown in Figure 3.25.The mean rating is 3.525 and the standard deviation is 0.923.

- Research and Development: The responses for research and development from medium to very high, as shown in Figure 3.25. Organizations ranked between 1 to 100, have rated themselves as high and very high. This implies that they are investing developing process and technologies that give them a competitive edge over their competitors. The mean rating is 3.525 and the standard deviation is 0.923.

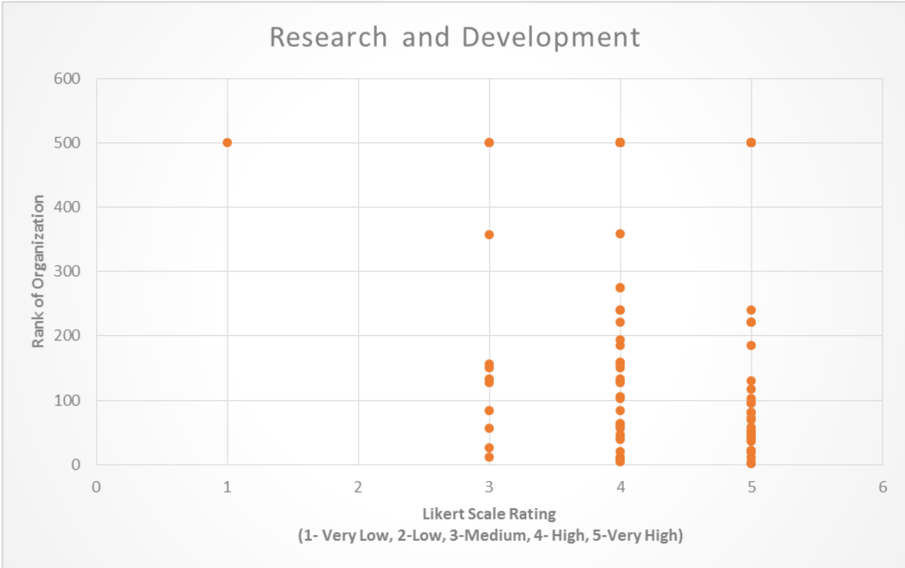

Figure 3.26.: Rating for Research and Development vs Rank of organization

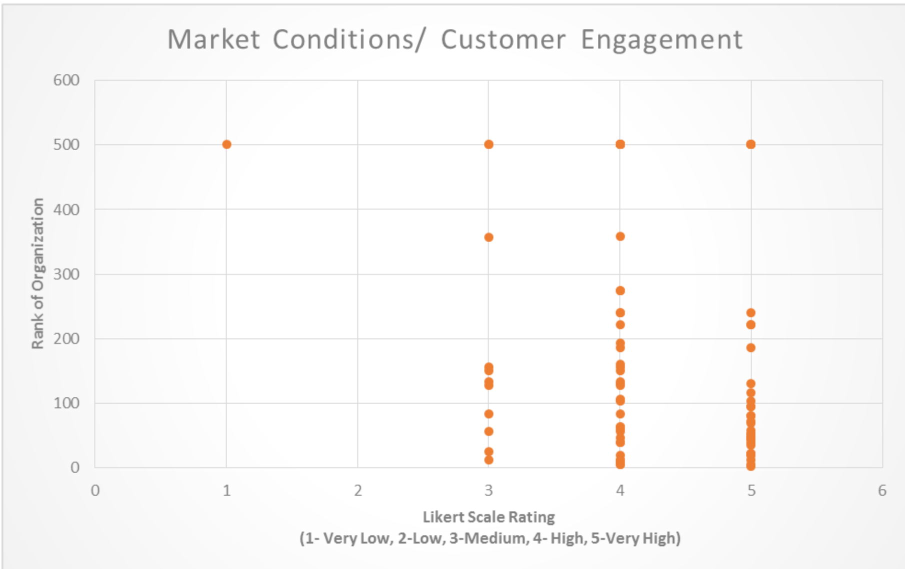

Figure 3.27.: Rating for Market Condition and Customer Engagement practices vs Rank of organization

- Market Condition/Customer Engagement: Understanding market conditions and being able to develop lasting relationships with customers is one of the most important ways of gaining business in construction industry. Since, most products can only be seen after the construction process and the samples are usually the previous projects, previous projects and relationships with clients provide companies with word of mouth recommendation. This is one of the most important form of marketing strategy in construction industry. The responses for this factor varies from medium to very high, as shown in Figure 3.27. Organizations ranked between 1 to 100, have rated themselves as high and very high. This implies that they are investing in developing process and technologies that give them a competitive edge over their competitors. The mean rating is 4.219 and the standard deviation is 0.7424.

Additionally, the financial information pertaining to the organizations was retrieved from ENR Top 400 Contractor and Top 500 Design firms Sourcebook publications. A longitudinal database was developed for revenue of different firms for past five years. The revenue earned in previous financial years was used to calculate annual growth rate, three year cumulative annual growth rate. The market diversification entropy was calculated from revenue percentage from different market segments for those organizations as shown in Figure 3.28.

3.9 Data Analyis

The total number of variables including qualitative and quantitative add up to 32 variables. Since the number of variables is very high, it is imperative to rank and determine the significant factors. To rank the factors Regression Best Subset Analysis was carried out using Minitab 17 and Analytic Hierarchy Process (AHP). Followed by Hierarchical Fuzzy Expert System modelling using Fuzzy Logic Toolbox Matlab 2015. The model will be tested and validated mathematically by Average Validity Percentage (AVP) and Average Invalidity Percentage (AIP).

ORGANIZATIONAL PERFORMANCE ASSESSMENT																
	FINANCIAL PARAMETER														MARKET CONDITION	
	Revenue		Market Segmentation									Productivity			Market Condition	
Response no.	Growth Rate 1 year	CAGR 3 year	General Building	Manufacturing	Power	WWS	Industrial/ Petroleum	Transportation	Hazardous Waste	Telecom	% CM at Risk	Revenue per employee ($ MIL)	No. of employees	Total number of years in business	Market Diversification entropy	RANK 2015
1	-0.16	-0.02	0.79	0.00	0.00	0.03	0.00	0.17	0.00	0.00	0.63	1.92	2539	83	0.257	1-100
2	-0.05	0.07	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	74	22	0.000	501
3	0.17	0.17	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.84	55	12	0.000	501
4	-0.05	0.07	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	74	22	0.000	501
5	0.21	0.11	0.77	0.07	0.03	0.00	0.00	0.01	0.00	0.12	0.01	0.94	2795	92	0.344	1-100
6	0.24	0.31	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	45	44	0.000	501
7	0.25	0.23	0.90	0.01	0.00	0.00	0.06	0.03	0.00	0.00	0.61	0.95	1081	84	0.180	1-100
8	0.05	0.07	0.20	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.26	3625	21	0.219	1-100
9	0.05	0.07	0.20	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.26	3625	21	0.219	1-100
10	0.05	0.07	0.20	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.26	3625	21	0.219	1-100
11	0.05	0.26	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.79	400	12	0.000	501
12	0.05	-0.11	0.83	0.06	0.00	0.00	0.01	0.09	0.00	0.01	0.79	1.79	700	72	0.275	1-100
13	-0.04	-0.01	0.15	0.18	0.00	0.08	0.58	0.01	0.00	0.00	0.01	0.65	884	51	0.503	100-200
14	0.05	-0.11	0.83	0.06	0.00	0.00	0.01	0.09	0.00	0.01	0.79	1.79	700	72	0.275	1-100
15	-0.31	-0.17	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	55	49	0.000	501
16	0.13	0.13	0.05	0.10	0.15	0.00	0.50	0.10	0.10	0.00	0.00	0.35	600	48	0.639	1-100
17	0.13	0.13	0.05	0.10	0.15	0.00	0.50	0.10	0.10	0.00	0.00	0.35	600	48	0.639	1-100
18	0.01	0.06	0.24	0.41	0.32	0.00	0.03	0.00	0.00	0.00	0.00	0.23	27750	22	0.512	1-100
19	0.17	0.17	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	55	12	0.000	501
20	-0.20	-0.06	0.68	0.00	0.00	0.00	0.00	0.28	0.01	0.00	0.00	0.17	119	77	0.289	501
21	-0.16	-0.02	0.79	0.00	0.00	0.03	0.00	0.17	0.00	0.00	0.63	1.92	2539	83	0.257	1-100
22	0.26	0.39	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41	138	30	0.000	100-200
23	0.26	0.39	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41	138	30	0.000	100-200
24	0.05	0.03	0.85	0.08	0.00	0.00	0.07	0.00	0.00	0.00	0.59	0.44	350	105	0.229	300-400
25	0.07	-0.15	0.81	0.02	0.00	0.03	0.01	0.00	0.00	0.14	0.91	0.42	360	100	0.293	501
26	0.07	-0.15	0.81	0.02	0.00	0.03	0.01	0.00	0.00	0.14	0.91	0.42	360	100	0.293	501
27	0.10	0.18	0.00	0.00	0.21	0.00	0.79	0.00	0.00	0.00	0.00	0.16	8000	37	0.223	1-100
28	0.10	0.18	0.00	0.00	0.21	0.00	0.79	0.00	0.00	0.00	0.00	0.16	8000	37	0.223	1-100
29	-0.34	-0.21	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.14	1100	33	0.000	501
30	-0.34	-0.21	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.14	1100	33	0.000	501
31	-0.27	-0.12	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.24	400	52	0.000	501
32	0.07	-0.15	0.81	0.02	0.00	0.03	0.01	0.00	0.00	0.14	0.91	0.42	360	100	0.293	501
33	0.04	0.02	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.49	956	118	0.000	501

Figure 3.28.: Financial data for organizations

3.10 Summary

This chapter has described the methodology used in this study. It provided the framework and methodology to be used in the research study. It has also provided a detailed description of data samples, how they were obtained, and how they were analyzed. The next chapter provides the details about the data analysis.

CHAPTER 4. DATA ANALYSIS

This chapter goes in depth to explain methods and steps involved in shortlisting variables. The author will first discuss the purpose of variable ranking and then explain the methodology in detail along with reasons for the chosen methodology and conclude with review and summation.

4.1 Significance of factors

The total number of independent variables, both qualitative and quantitative, add up to total of 32 variables. The number of variables is very large and hence to perform further analysis, we need to shortlist the factors that really contribute to the performance of an organization. For initial analysis of data to check for co-relation between variables, regression analysis using Minitab 17 was carried out. The results from Regression analysis were R_{sq} equal to 99.1% and R_{sq} (adj) equal to 97.7%. Such results do not indicate high co-relation between factors, instead the number of variables are very large and no co-relation could be identified. Hence, making it all the more necessary to reduce the factors. Different methods exist to shortlist the factors. Since, we are dealing with 18 number of qualitative factors, the Analytic Hierarchy Process will be a suitable method to determine the significance of factors by comparison with other factors within a category.

4.2 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), developed by Thomas Saaty in 1977, is a multi-criteria decision making process of qualitative factors when arranged in a hierarchical process (Saaty, 1990). The process allows to solve complex decision, by aiding users in organizing information pertaining to thoughts, knowledge and judgement into a hierarchical framework and quantify the effect of qualitative factors by a sequence of pair-wise comparison judgements (Saaty, 1990). In this study, AHP has been used to evaluate the significance of impact of qualitative factors on overall organizational performance. The basic procedure to carry out AHP consists of following steps:

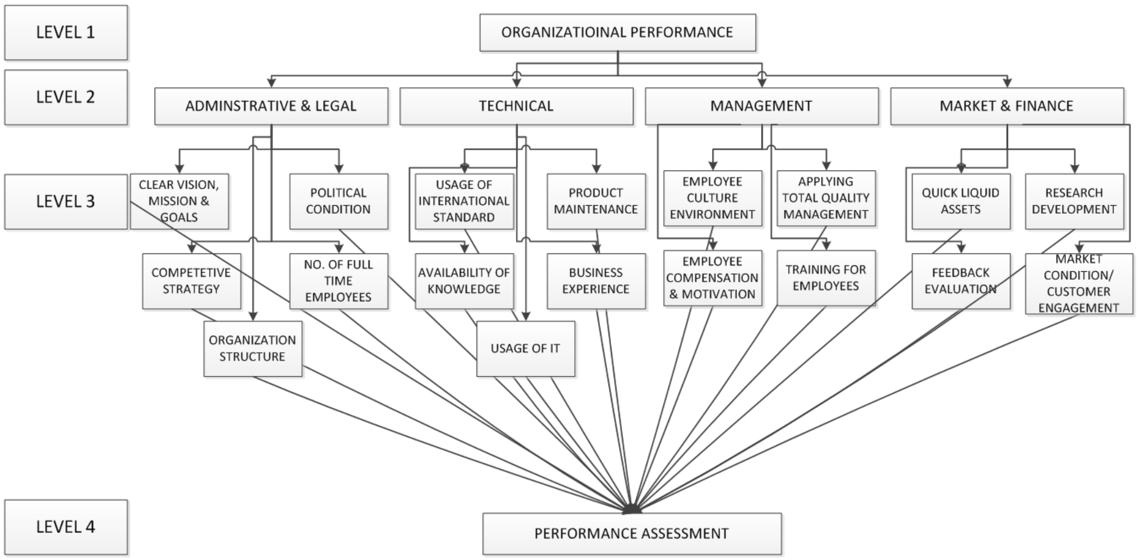

Figure 4.1.: Layers in Analytic Hierarchy Process

1. First, the hierarchy of factors is established and selection of criteria. The top most level focuses on the goal of the problem in our case it the Organizational Performance. The intermediate levels contain the qualitative or non-financial parameters, that are categorized into four main categories in (i.e. Administrative and Legal, Technical, Management and Market and Finance). The next level or sub-level includes 18 sub-factors (i.e. Clear Vision, Mission and Goals, Competitive Strategy, Organizational Structure, Political Conditions, Number of Full Time Employees, Usage of International Aspects (ISO), Availability of knowledge Usage of IT, Business Experience, Product Maintenance, Employee Culture Environment, Employee Compensation and

Motivation, Applying Total Quality Management, Training, Quick Liquid Assets, Feedback Evaluation, Research and Development and Market Conditions/Customer Engagement. The layout of hierarchy helps decision makers to assess the relationship between factors and the assessment whether the factors are of same magnitude (Fares & Zayed, 2010). Please refer Figure 4.1.

2. Second step involves priority setting of criteria by pair-wise comparison matrices for main factors. Based on the impact rating of the 18 factors, a matrix is assigned with overall rating for four main factors, i.e. Administrative and Legal, Technical, Management and Market and Finance and their sub factors. Figure 4.2 shows the analysis of pair-wise comparison matrices for average values of main factors and their sub-factors.

3. Third step is assigning priorities and establish pair-wise comparison for sub-factors within each main category. This step involves average values of sub-factor with in one main factor. The AHP methodology applied to these matrices gives the weight factor of each factor (W_i). Table 4.1 shows the weights of factors.

4. Fourth step is Consistency Analysis. This step verifies the consistency of pair-wise comparison matrix. Weights can be accepted only if the matrix is consistent. Therefore, consistency index (CI) and consistency ratio (CR) will be calculated as follows (Fares & Zayed, 2010):

$$CI = \frac{\lambda_{max} - m}{m - 1}$$

$$CR = \frac{CI}{RI}$$

   Where, CI= the matrix consistency index.

   m= matrix size

   λ_{max} =the maximum eigen value.

Factors pairwise comparison matrix

Factors	Administrative & Legal	Technical	Management	Market & finance
Administrative & Legal	1	28.13/26.53	28.13/23.49	28.13/21.85
Technical	26.53/28.13	1	26.53/23.49	26.53/21.85
Management	23.49/28.13	23.49/26.53	1	23.49/21.85
Market & finance	21.85/28.13	21.85/26.53	21.85/23.49	1
	28.13	26.53	23.49	21.85

Administrative & Legal sub-factors pairwise comparison matrix

	Clear Vision Mission & Goals	Competetive Strategy	Organization Structure	Political Conditions	No. of Full time Employees
AVERAGE	4.08	3.94	3.79	2.89	3.56
STD DEV	0.96	0.87	1.01	1.12	0.99

Factors	Clear Vision Mission & Goals	Competetive Strategy	Organization Structure	Political Conditions	No. of Full time Employees
Clear Vision Mission & Go	1	1.03093946	1.08732735	1.432311225	1.150189787
Competetive Strategy	0.969989062	1	1.05469563	1.389326222	1.115671513
Organization Structure	0.919686241	0.94814084	1	1.317276926	1.057813721
Political Conditions	0.698172284	0.71977336		1	0.803030631
No. of Full time Employee	0.869421735				1
	22.4353	21.7620	20.6334	15.6637	19.5057

Figure 4.2.: Pairwise comparison matrix

RI= random index (refer Table 4.2)

5. Table 4.1 shows CI and CR for main factors. It also shows that CI for main factors is 0.00000149 and CR is 0.00, which is less than 0.10. It means the

Table 4.1: Eigen Vector Weights (W_i)for main factors

Factors	**WEIGHT (Wi) EIGEN VECTORS**	**C.I.= max-N/N-1**	**C.R.=C.I./R.I=**
Administrative & Legal	0.2813	0.00000149	0.00000000
Technical	0.2653		
Management	0.2349		
Market & finance	0.2185		

Table 4.2: Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 4.3: Factor and sub-factor weights

Factors	Ave. Weight-Main Factors	Ave. Sub-factors Weight	Ave. Decomposed Weight
Administrative & Legal	**0.2813**		
Clear Vision Mission & Goals		0.2244	0.0631
Competitive Strategy		0.2176	0.0612
Organization Structure		0.2063	0.0580
Political Conditions		0.1566	0.0441
No. of Full time Employees		0.1951	0.0549
Technical	**0.2653**		
Usage if International Standards (ISO)		0.1336	0.0355
Availability of Knowledge		0.2284	0.0606
Usage of IT		0.2159	0.0573
Business Experience(no. of years)		0.2338	0.0620
Product Maintenance		0.1883	0.0499
Management	**0.2349**		
Employee Culture Environment		0.2696	0.0633
Employee Compensation and Motivation		0.2495	0.0586
Applying Total Quality Management (TQM)		0.2207	0.0518
Training for employees		0.2601	0.0611
Market & finance	**0.2185**		
Employee Culture Environment		0.2361	0.0516
Employee Compensation and Motivation		0.2462	0.0538
Applying Total Quality Management (TQM)		0.2140	0.0468
Training for employees		0.3037	0.0663

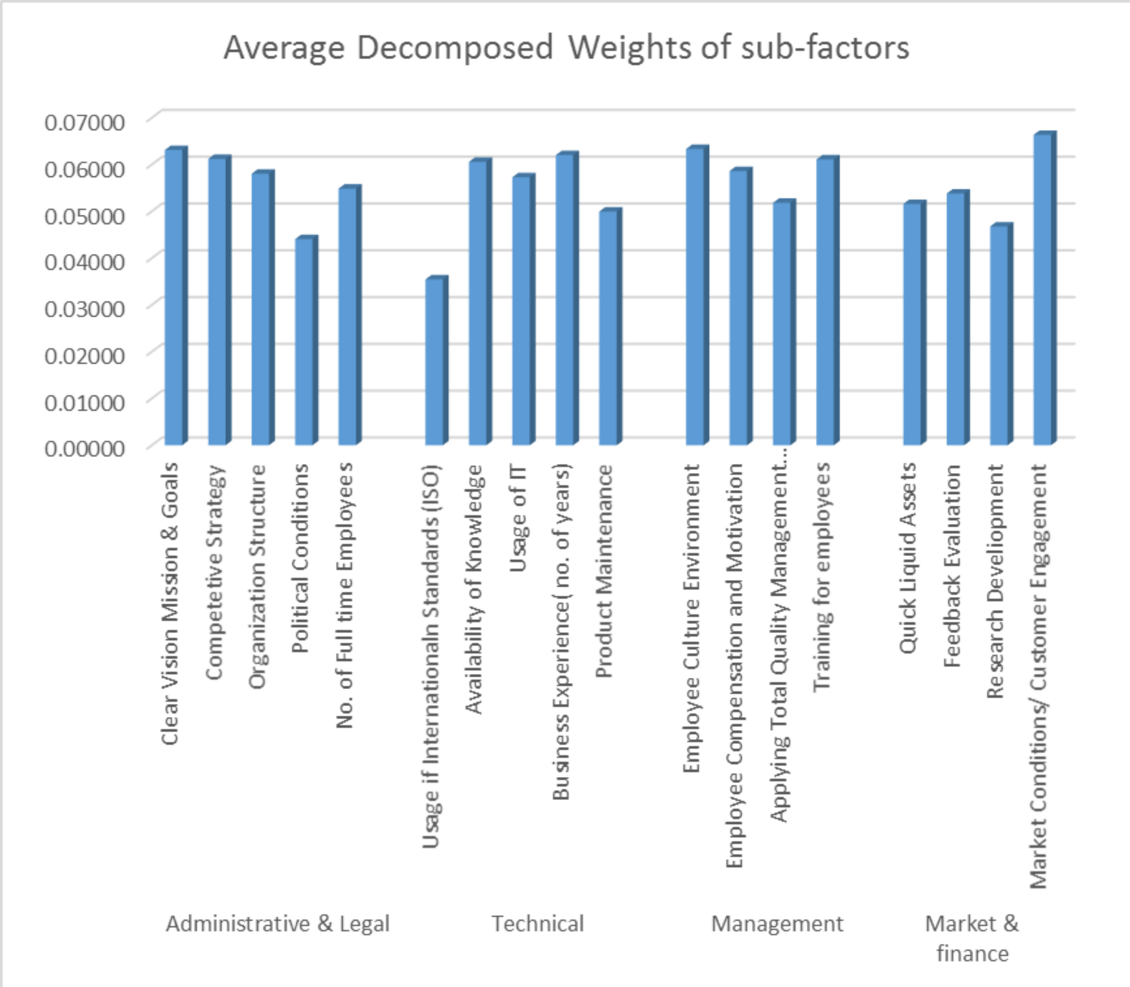

Figure 4.3.: Decomposed weights for sub-factors

main matrix is consistent and the weight vectors generated for this matrix are acceptable.

6. The process is repeated for sub-factors, Table A.1 shows weights for main factors and sub-factors, followed by calculation of Average Decomposed weight. The decomposed weight is calculated by multiplying the main factor weight by its sub-factor weight. The decomposed weight will represent the

overall weight of each sub-factors (Fares & Zayed, 2010). Overall Sub-factor Decomposed Weight

$$(SDW_{ij}) = W_i * (V_{ij})$$

Where, W_i= Weight of factor i

V_{ij} = Weight of sub-factor j within the factor i

7. The graphical presentation in Figure 4.3 shows the Average decomposed weights. Going through the average decomposed weights, it can be seen that the weight of factors are ranked very closely. In this case, it becomes essential that an appropriate cutoff wright is chosen to shortlist factors. To select a cut-off weight we need to consider the mean of the average weights and find the largest difference in weights between two factors. The average decomposed weights of all sub-factors is 0.0556. The difference between the weights of sub-factor Availability of knowledge and Employee Compensation and Motivation is 0.00197. Hence, this is taken as the cut-off weight. Thus, from the AHP method, we have shortlisted seven factors, i.e. Market condition/Customer Engagement, Employee Culture Environment, Clear Vision Mission Goals, Business Experience, Competitive Strategy, Training for Employees and Availability of Knowledge. To verify the factors, the next step is to verify the results with stepwise regression in Minitab 17.

4.3 Regression Analysis

The first attempt to analyze the data using regression analysis obtained R_{sq} as 99.7% and R_{sq}adj as 97.2%. As mentioned this was as a result of large number of variables. In order to shortlist the variables further and to verify the results achieved from AHP, the best subset regression function was used. In this step, the Best Subset Regression function was used where R_{sq} increase with number of variables added to the equation, however, R_{sq}(adj) varies as a peak and increases only if the added variable contributes to better fit of the equation. The best subset reported is the highest R_{sq} and R_{sq}adj value. Also, the Mallow's coefficient C_p should be equal or close to equal to number of variables (Fares & Zayed, 2010).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	35	6.56633	0.18761	8.94	0.000
Growth Rate 1 year	1	0.00738	0.00738	0.35	0.557
CAGR 3 year	1	0.00000	0.00000	0.00	0.994
General Building	1	0.01751	0.01751	0.83	0.367
Manufacturing	1	0.31135	0.31135	14.84	0.000
Power	1	0.12741	0.12741	6.07	0.018
WWS	1	0.41737	0.41737	19.89	0.000
Industrial/Petroleum	1	0.13373	0.13373	6.37	0.016
Transportation	1	0.01401	0.01401	0.67	0.419
Hazardous Waste	1	0.41514	0.41514	19.78	0.000
Telecom	1	0.28151	0.28151	13.42	0.001
% CM at Risk	1	0.03735	0.03735	1.78	0.190
Revenue per employee ($ MIL)	1	0.23409	0.23409	11.16	0.002
No. of employees	1	0.01378	0.01378	0.66	0.423
Total number of years in busine	1	0.04532	0.04532	2.16	0.150
Market Diversification entropy	1	1.08508	1.08508	51.71	0.000
Clear Vision Mission & Goals	4	0.48514	0.12129	5.78	0.001
Competetive Strategy	2	0.64494	0.32247	15.37	0.000
Availability of Knowledge	3	0.03245	0.01082	0.52	0.674
Business Experience(no. of yea	3	0.28859	0.09620	4.58	0.008
Employee Culture Environment	3	0.30152	0.10051	4.79	0.006
Training for employees	3	0.05757	0.01919	0.91	0.443
Market Conditions/ Customer Eng	2	0.11039	0.05520	2.63	0.085
Error	39	0.81834	0.02098		
Total	74	7.38467			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.144855	88.92%	78.97%	55.04%

Figure 4.4.: Regression analysis for variance for best subset.

For this data, the best subset identified included 20 factors (qualitative and quantitative). After multiple iterations for various subsets shortlisted from AHP, the best subset analysis was carried out. The highest R_{sq} value achieved was 88.92%, R_{sq}adj as 78.97% and R_{sq}predicted as 55.04%, refer figure 4.4. Figure 4.5 shows the

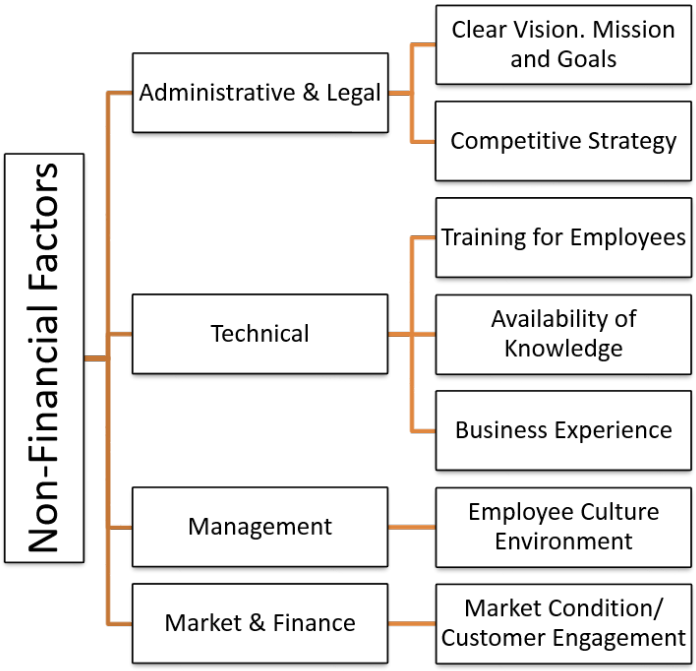

Figure 4.5.: Shortlisted qualitative variables

seven shortlisted qualitative varables for modelling purpose. The low R_{sq}pred value indicates that this model has very low prediction rate. There are two main reason for this. Firstly, the equation deals with human opinion which are highly qualitative and difficult to model. Secondly, the majority of participants who responded in the survey fall between rank 1 to 200. Therefore, this model can best predict ranking for organizations that fall between this range. This was the main reason for not utilizing regression prediction model to assess organizational performance assessment.

4.4 Fuzzy Logic Modelling

Human reasoning being more approximate than precise in nature often makes it difficult to measure and determine the measure of factors affecting a particular cause. Introduced by Zadeh (1965), Fuzzy logic can be used as a tool to understand imprecision and qualitative aspects of natural language and imprecise cognitive reasoning. Fuzzy logic-based systems are used to analyze and process linguistic inputs to derive outputs or decisions (Senouci, El-Abbasy, & Zayed, 2012). Matlab R2015a Fuzzy Logic Tool Box software is used to process fuzzy logic inference.

4.4.1 Hierarchical Fuzzy Expert System

The hierarchical fuzzy model consists of sub-models, which correspond to the three main categories. In addition to the sub-model there will be one more model that combines the outputs of these sub-models in order to generate the rank of of the organization. The fuzzy structure of each of the models is identical. The membership function assigned to input variables and the knowledge based rules differ. When dealing with high number of variables, like in this study, the total number of shortlisted independent variables are 20, developing a single layer fuzzy model is not recommended.

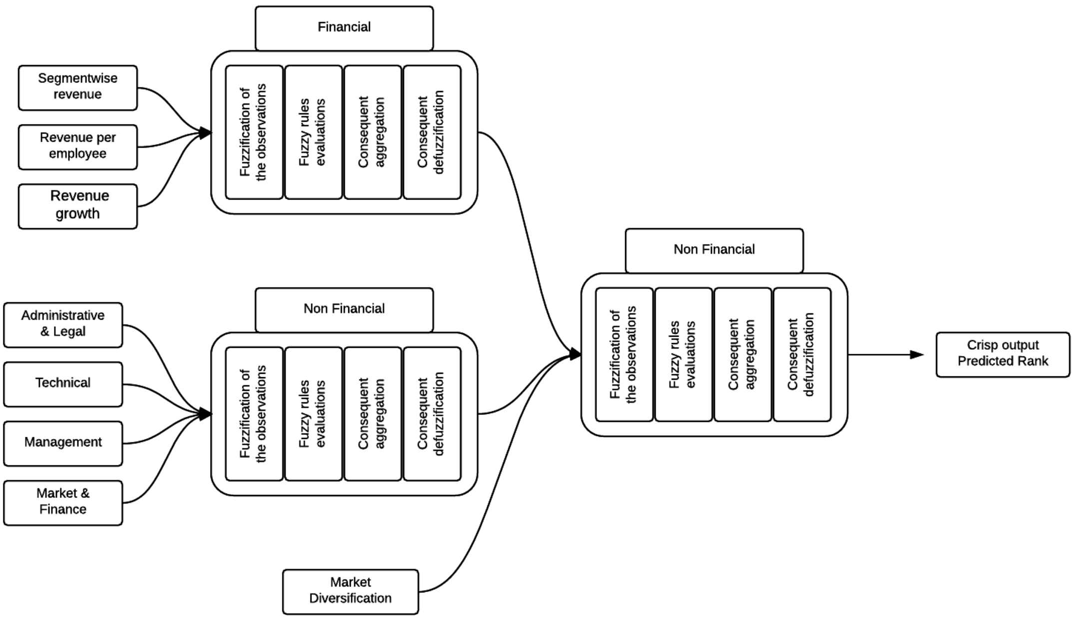

Figure 4.6.: Overall Hierarchical Fuzzy Model

As the qualitative variables were measured on different scale compared to quantitative variables. For example, annual growth rate is measure in percentage and entropy was measured in fraction or decimal values. Assigning weight to the membership on one layer is extremely difficult. The weight for individual factor can be used for comparison with the same category, however, a sub-factor from non financial category cannot be compared to sub-factors from financial category.

Additionally, for every variable there should be seven-nine rules. To build a one layer fuzzy model the minimum number of rules required will be more than 140 rules for 20 variables. The hierarchical model allows us to work with less number of rules. The sub-model for this study will be built using only 7-8 factors (Fayek & Tsehayae, 2012). With usable data set of 75 responses from the survey, the hierarchical system will allow us to develop the prediction model. The set of responses required for knowledge based rule training and testing will be satisfied. There will be total three models, two sub-models for financial and non financial factors and the third model will be second layer of fuzzy model which will combine inputs of financial, non financial and market diversification factor as shown in Figure 4.6. Since, there is only one factor under market diversification, a separate sub-model will not be developed. The steps involved are as following:

4.4.2 Assigning Membership Function

Existing literature review shows that different form of membership function are used depending on the type problem. The factor's fuzzy membership is such that the real input can be converted in to fuzzy number value in range [0,1].

1. For all the independent variables, the values were normalized so that they could be brought to scale between 0.0 to 1.0. The normalized data as attached in Appendix A was calculated using the formula below

$$z_i = (X_i - X_{min})/(X_{max} - X_{min})$$

Table 4.4: Membership function range value

Range	Membership Function
0.0-0.2	Very High
0.2-0.4	High
0.4-0.6	Moderately low
0.6-0.8	Low
0.8-1.0	Very Low

2. The independent variables are assigned gaussian membership function with range from 0.0 to 1.0. In this study, we are dealing with expert opinions and hence instead of giving it crisp boundary, it is assigned a wave form membership. The membership function value and the corresponding range is as shown in Table 4.4.

3. The relative weight of each factor at the first level of hierarchy is determined. The normalized global weights calculated for each main factor and sub-factor. This step was carried out for sub-factors of financial and non-financial categories. Since, only one factor falls under market diversification, the weight of only one factor was calculated at the factor level. The normalized global weights allow the sub-factors to be compared to each other. The globalized weight is calculated by multiplication of weight of individual sub factor to the weight of main factor (Fares & Zayed, 2010). The last column shows the normalized global weights. It shows that the Market condition and Customer Engagement is factor with highest weight at 1.000, closely followed by employee culture environment which is second highest at 0.984, refer Table 4.5.

4. The next step, involves developing of if-then rules, that is, the impact of sub-factor on the output, as shown in Table 4.6.

Table 4.5: Factor and sub-factor weights, globalized weights and normalized weights

Main Factors	Factor weight	Sub-factor	Sub-factor weight	Std Dev	Global Weight	Normalized global weights
NON FINANCIAL	64.84	Clear Vision Mission & Goals	15.21	4.14	986.41	0.904
		Competetive Strategy	15.30	4.31	991.92	0.910
		Availability of Knowledge	15.21	3.29	986.41	0.904
		Business Experience(no. of yea	8.35	4.93	541.60	0.475
		Employee Culture Environment	16.49	4.19	1069.07	0.984
		Training for employees	12.69	4.68	822.92	0.747
		Market Conditions/ Customer Eng	16.74	3.79	1085.60	1.000
FINANCIAL	30.10	Growth Rate 1 year2	9.37	5.22	282.11	0.225
		CAGR 3 year3	18.37	9.34	552.88	0.486
		General Building4	28.54	18.35	858.96	0.781
		Manufacturing5	2.90	6.44	87.33	0.037
		Power6	4.21	8.95	126.62	0.075
		WWS7	2.16	5.46	64.90	0.016
		Industrial/Petroleum8	7.97	17.28	239.97	0.184
		Transportation9	3.13	6.54	94.32	0.044
		Hazardous Waste10	1.62	6.31	48.79	0.000
		Telecom11	2.33	5.93	70.13	0.021
		% CM at Risk12	10.77	13.59	324.10	0.266
		Revenue per employee	8.63	7.13	259.90	0.204
MARKET	5.06	Diversification Entropy	100	0	506.07	0.441

Table 4.6: If-then rules for sub-factors

Factor		**Impact on organizational performance**		
if Clear Vision Mission & Goals is	Very High	then	Impact of non financial factor	Very High
if Clear Vision Mission & Goals is	High	then	Impact of non financial factor	High
if Clear Vision Mission & Goals is	Moderately low	then	Impact of non financial factor	Moderately low
if Clear Vision Mission & Goals is	Low	then	Impact of non financial factor	Low
if Clear Vision Mission & Goals is	Very Low	then	Impact of non financial factor	Very Low

5. The independent factors serve as the input factors. The normalized input values of the linguistic variables are multiplied by the sub-factor weight to evaluate the equivalent impact, as shown in Table 4.7. The sum of all the sub-factor's equivalent impact value is the combined impact of the sub-factors, which is also the crisp output value for the first level of hierarchy.

6. The crisp output value received from first layer of hierarchical fuzzy model acts as input for the next layer of hierarchy model. Refer fig 4.7.

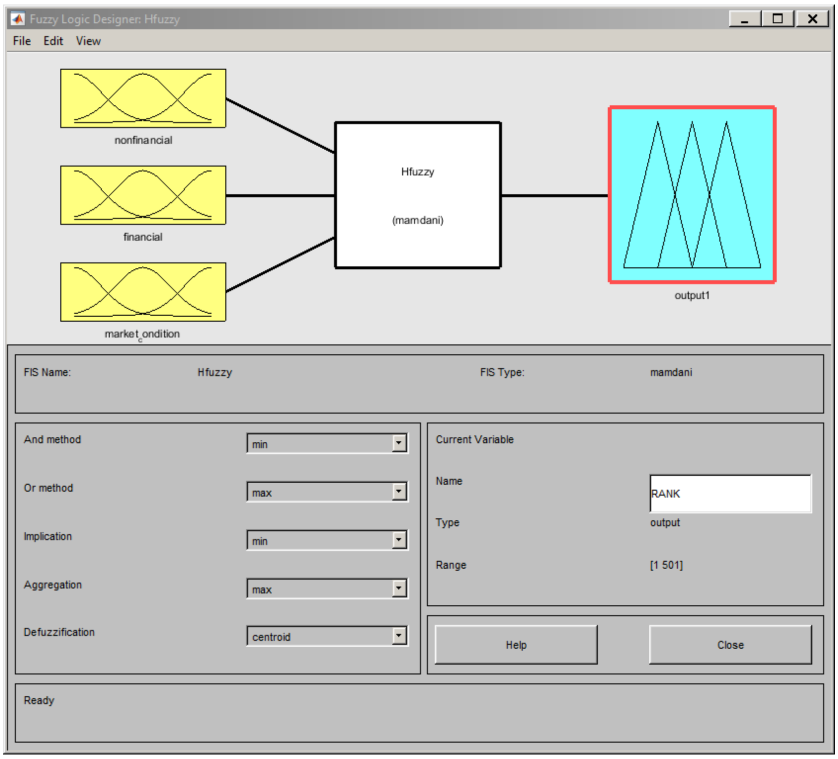

Figure 4.7.: Second level of Hierarchical Fuzzy model developed using Fuzzy Logic Toolbox

7. The second level of the hierarchical fuzzy model is developed using the Fuzzy Logic Toolbox in Matlab R2015, as shown in Figure 4.7. The input variables for the second layer which are numeric values are assigned membership functions.

Table 4.7: Sub factor weights and equivalent impact

Rule no.	Clear Vision	Competitive Strategy	Availability of Knowledge	Business Exp	Employee Culture	Training employees	Market Conds/ Customer Eng	Equivalent Iimpact	Combined Impact
	15.21	**15.30**	**15.21**	**8.35**	**16.49**	**12.69**	**16.74**		
1	0.75	0.50	0.75	0.50	0.75	0.33	0.75	6.38	High
2	0.75	0.50	0.75	0.04	1.00	0.67	1.00	7.25	High
3	0.75	0.75	1.00	0.56	1.00	1.00	1.00	8.87	Very high
4	0.75	0.50	0.75	0.51	1.00	0.67	1.00	7.64	High
5	0.75	1.00	0.75	0.10	0.75	0.67	0.75	7.24	High
6	1.00	0.75	1.00	0.10	1.00	0.67	1.00	8.44	Very high
7	1.00	1.00	0.75	0.43	0.75	0.67	1.00	8.31	Very high
8	1.00	1.00	1.00	0.43	0.50	1.00	1.00	8.70	Very high
9	0.50	0.50	0.50	0.28	0.50	0.33	0.50	4.61	Moderate
10	1.00	1.00	1.00	0.28	1.00	1.00	1.00	9.39	Very high
11	0.75	0.75	0.50	0.28	0.50	0.33	1.00	6.20	High
12	1.00	0.75	0.50	0.11	1.00	0.33	1.00	7.27	High
13	0.25	1.00	0.50	0.04	0.25	0.33	0.75	4.80	Moderate
14	0.50	0.50	1.00	0.46	0.50	0.67	0.75	6.36	High
15	1.00	0.75	1.00	0.50	1.00	1.00	0.75	8.78	Very high

8. The input membership function shape is assigned guassian wave membership with five membership functions for each main factor. The range of each membership function is from zero to one. As shown in Figure 4.8

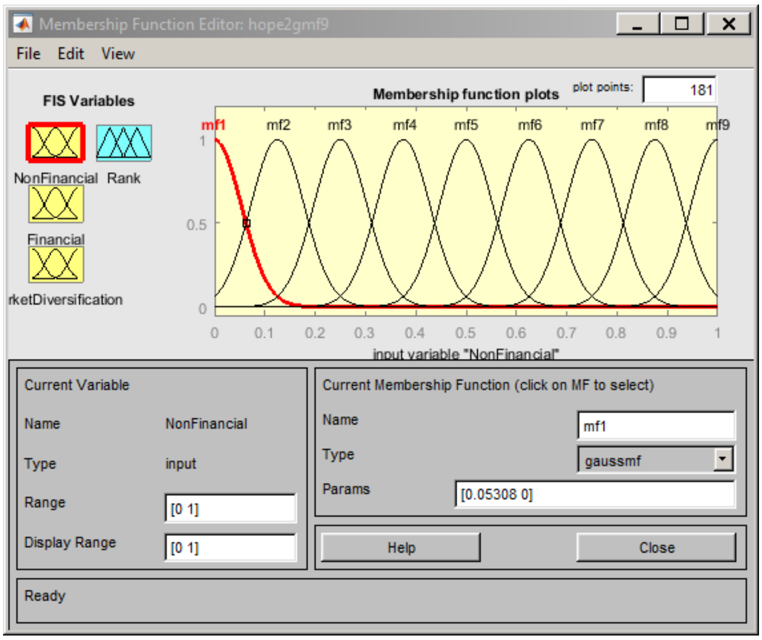

Figure 4.8.: Membership functions assigned to input variable

4.4.3 Fuzzy Inference

The Mamdani type fuzzy model is selected in the fuzzy logic toolbox of Matlab R2015 with maximum and minimum rule. The mamdani is easier to understand and work with consequent of the systems. The Mamdani method uses a simple structure of Minimum operator, as shown in equation below:

$$R^j : \; If \; x_1 \; is \; A_1^j \; and x_2 \; is \; A_2^j \; and \; x_3 \; is \; A_3^j \; and....x_n \; is \; A_n^j \; then \; y \; is \; B^j$$

Where R^j is the j-th rule, A_i^j (j= 1,2, N,i=1,2,n), B^j are the fuzzy subsets of the inputs and outputs respectively. This rule can be written mathematically (Fares, 2008; Jin 2003) as

$$\mu_R{}^j(x_1, x_2, x_3, \ldots\ldots, x_n, y) = \mu_{A_1}{}^j \wedge \mu_{A_2}{}^j \wedge \mu_{A_3}{}^j \ldots\ldots \wedge \mu_{A_n}{}^j \wedge \mu_B$$

The minimum operator is used to calculate the firing strength of each fuzzy rule. The firing strength is directly proportional to the impact on the output. The rules are setup up in the if-then format as shown in Figure 4.9

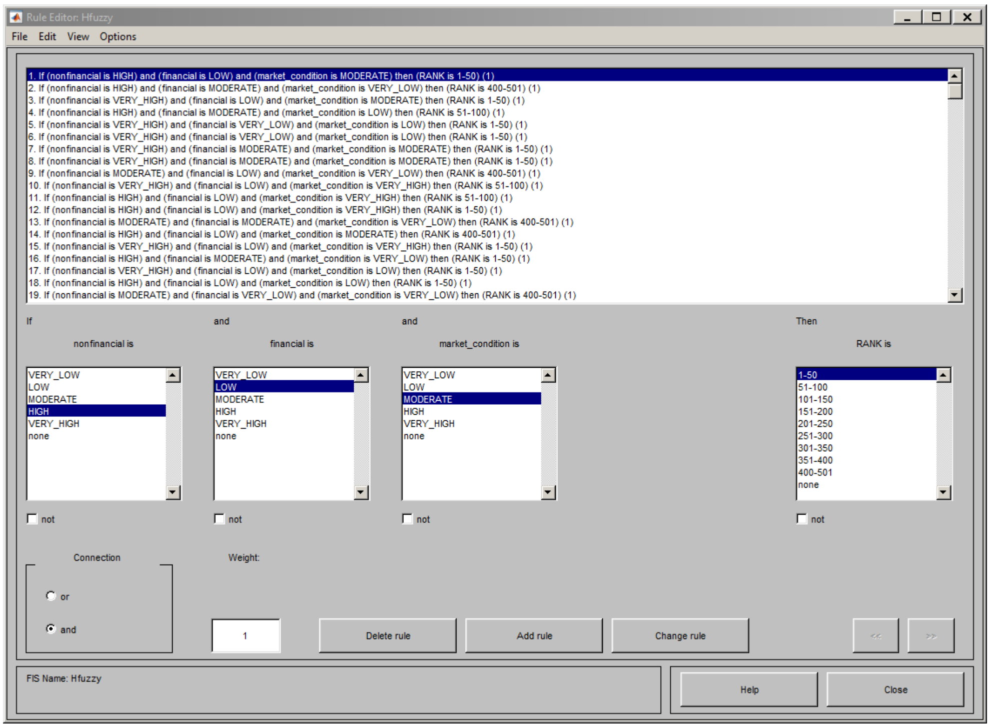

Figure 4.9.: If-then rule setup

4.4.4 Defuzzification

There are multiple defuzzification methods. In this study, the output factor is assigned triangular shape with nine membership functions. The reason for nine membership function is to increase the sensitivity and accuracy of model, as shown

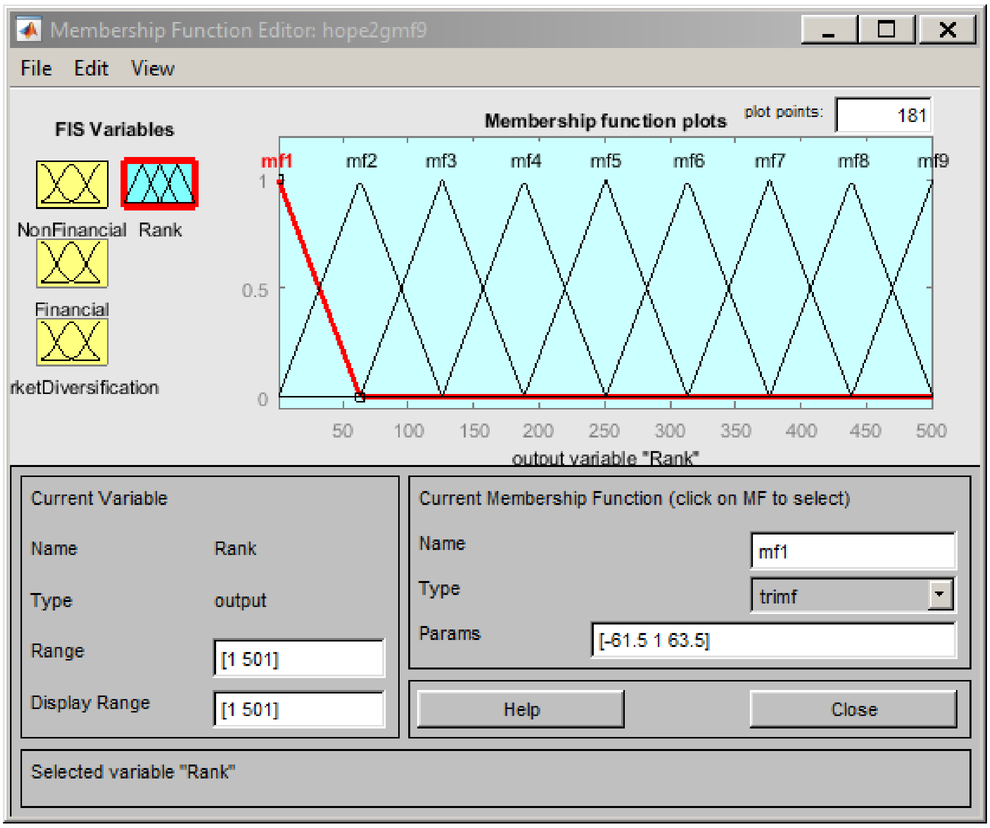

Figure 4.10.: Membership function assigned to Output variable

in Figure 4.10. Output membership function maps the height corresponding to the firing strength of rules (Chao & Skibniewski, 1998). In this layer of fuzzy process, the output values are obtained by defuzzified value of centroid of the triangular membership assigned to the output variable. This numeric output is the predicted rank of the organization as shown in Figure 4.12.

4.5 System Analysis and Verification

Two methods have been used to test and verify the developed model and system. First approach is to determine the sensitivity or stability of model by assessing the efect of the different factors on the model behaviour. For this purpose the in-built tool surface is used to see the model behavior. The second approach is

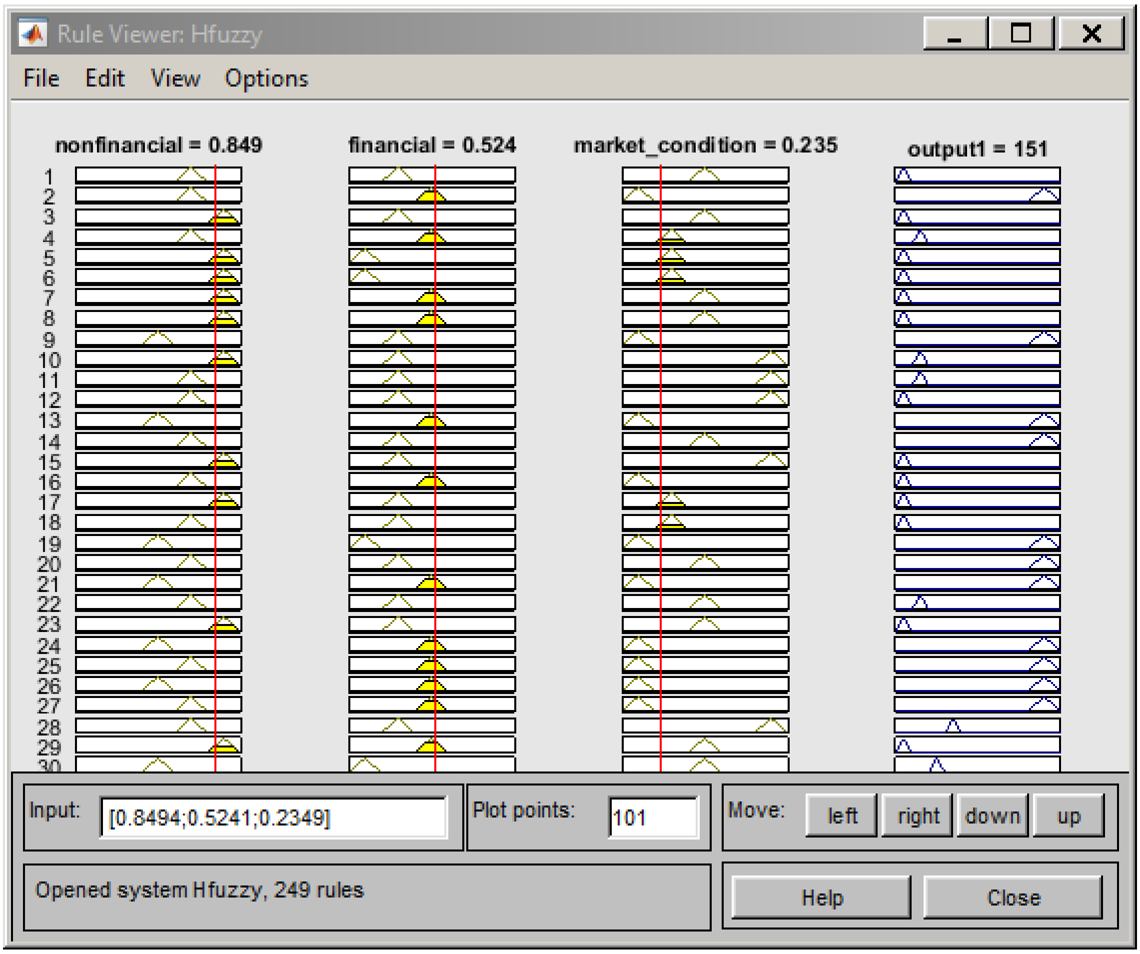

Figure 4.11.: Fuzzy rule output

model accuracy testing which uses results from regression model to verify the results of developed model.

4.5.1 System Analysis

To ensure that the model is sensitive and stable to perform under different parameters this model is tested by validation rule set. As seen in the Figures 4.13, 4.14 and 4.15.

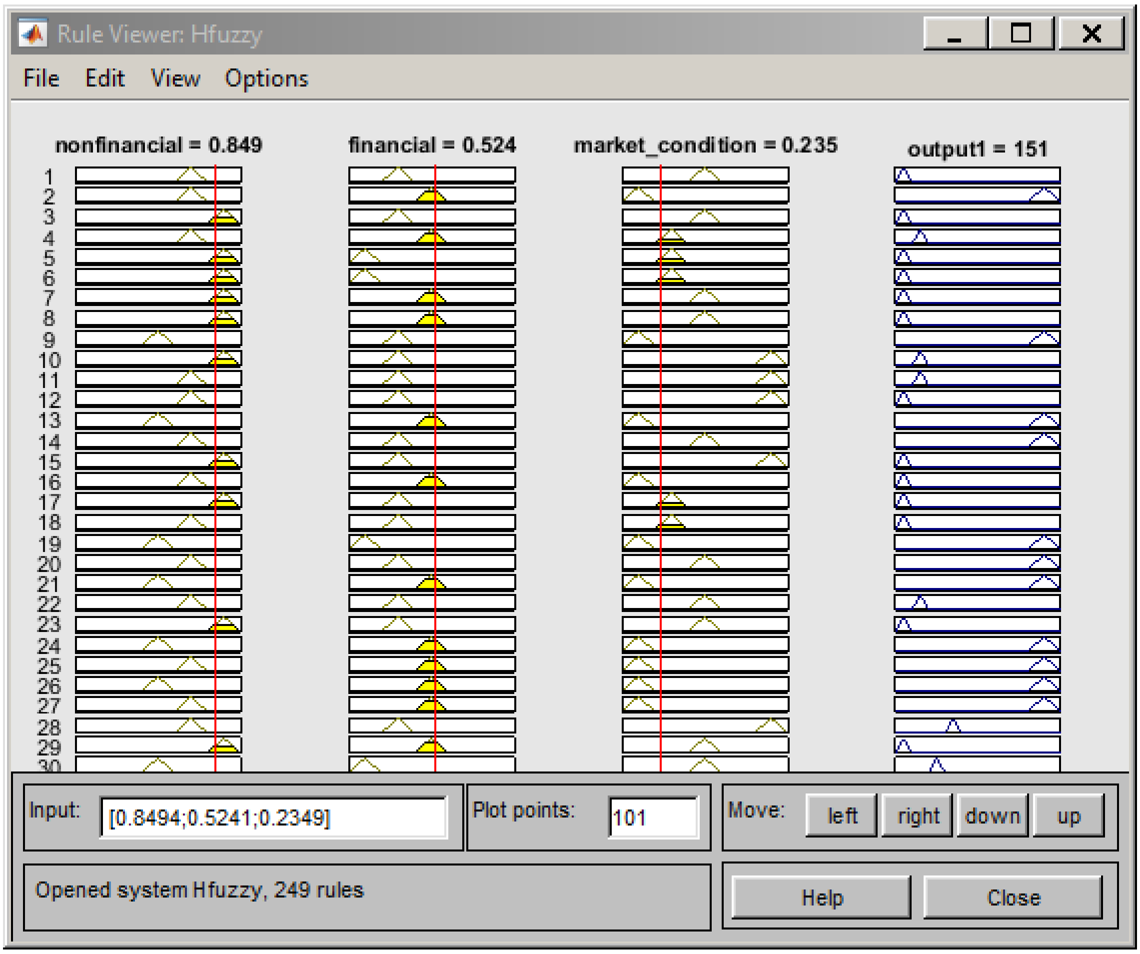

Figure 4.12.: Fuzzy rule output

4.5.2 Verification of the Developed Model

To verify the developed model, 20% of the data set was left untouched for testing purposes. To determine whether the model is verified or not when using results comparison as in this study, two terms can be used to determine the validity of the model, Average Validity Percent (AIP) and Average Invalidity Percent (AIP). AVP represents the validation percent out of 100 and AIP represents the prediction error (T. M. Zayed & Halpin, 2005). These two terms are shown in Equation below:

$$AIP = ((\sum_{i=1}^{n} |1 - (E_i \div C_i)|)) \div n \tag{4.1}$$

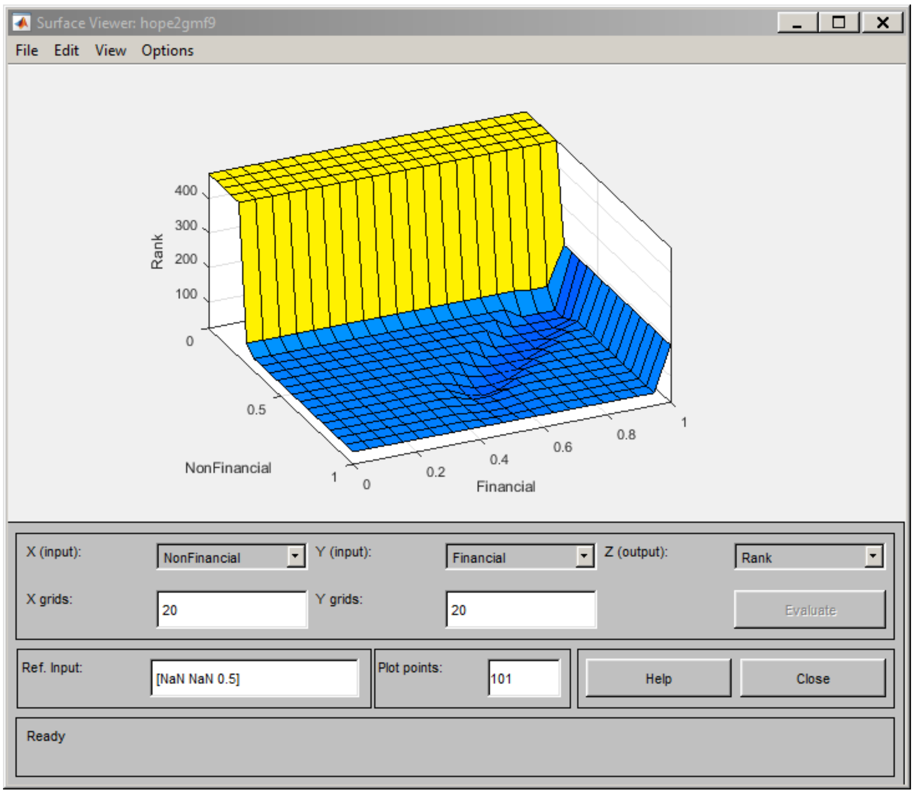

Figure 4.13.: Model behavior for Financial vs Non-Financial with respect to Rank

$$AVP = 1 - AIP \tag{4.2}$$

Where

AIP : Average Invalidity Percent

AVP : Average Validity Percent

E_i : Estimated value

C_i : Actual value

Table 4.8 shows the validation data with comparison of categories of actual organization rank and the predicted category of organization rank. The Average Invalidity Percentage is 36.667%. Therefore, the average validity percentage is 64.334%. Thus the model is stable.

Table 4.8: Validation results

Rank Category (C)	Predicted Rank Category (E)	ABS(1-(E/C))
1	1	0.00
2	1	0.50
4	1	0.75
5	5	0.00
1	1	0.00
2	2	0.00
3	1	0.67
3	1	0.67
2	5	1.50
3	1	0.67
1	1	0.00
3	5	0.67
1	1	0.00
1	1	0.00
2	2	0.00
	AIP%	**36.11**

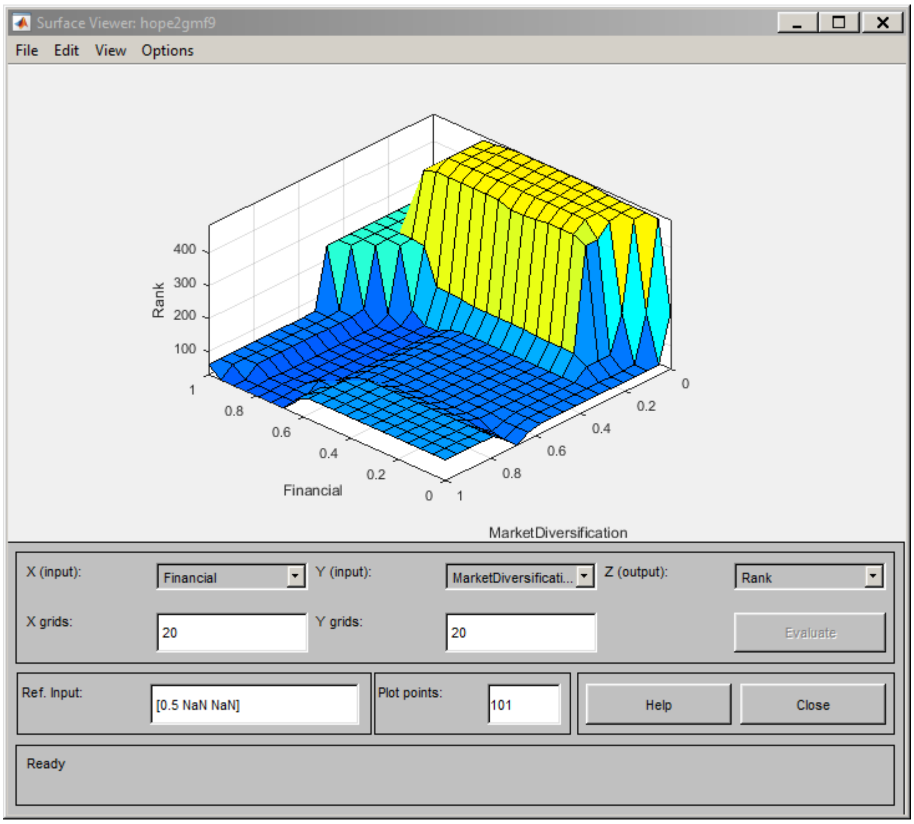

Figure 4.14.: Model behavior for Financial vs Market Diversification with respect to Rank

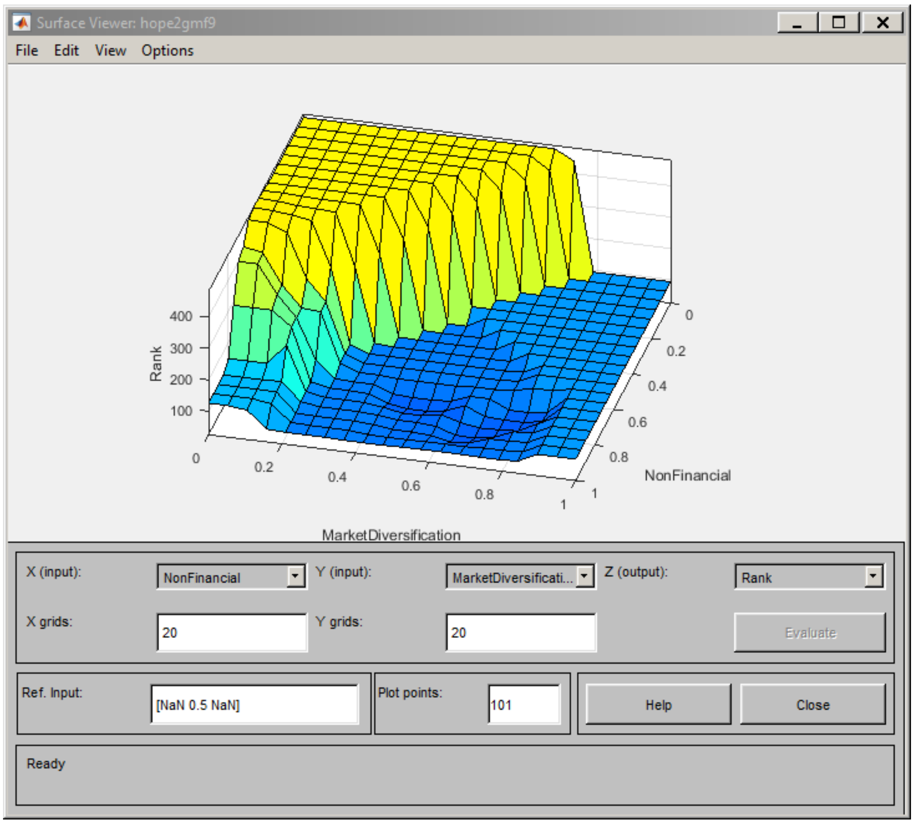

Figure 4.15.: Model behavior for Non-Financial vs Market Diversification with respect to Rank

CHAPTER 5. CONCLUSION

5.1 Summary

The performance of a construction organization is dependent on several success factors. Only few research studies have focused to identify and measure the non-financial performance of the construction organization.The present study includes a literature survey to validate the importance of critical success factors identified in previous studies. This paper represents development of a comprehensive framework to assess the performance of construction organizations based on 20 factors categorized into financial, non-financial and market diversification, using hierarchical fuzzy approach. The seven qualitative or non-financial critical success factors (i.e. Clear Vision, Mission, and Goals, Competition Strategy, Availability of Knowledge, Business Experience (no. of years), Employee Culture Environment, Market condition and Customer Engagement) were selected using Analytic Hierarchy Process (AHP) ranking system. In order to assess the combined impact of factors on the overall organization performance, they have been modelled using hierarchical fuzzy expert system. Fuzzy input and outputs and the rules governing them are designed using the data responses collected from industry professionals. The study will be a step towards understanding a detailed analysis of factors that may impact the overall performance.

5.2 Conclusion

During the course of this research, multiple points of observation and concern have been concluded from data response and analysis, such as:

- It can be deducted from the collected questionnaire that industry professionals rate the impact of Customer Engagement and Employee Cultural Environment as very high.

- The ranking of impact of critical success factors such as Product Maintenance, Research and Development, Usage of International Standards and Political conditions is very low. The average decomposed weight from the AHP process shows that construction industry rates impacts of investment in Research and Development of in-house technologies as low and medium. They mainly rely on the products from computing firms.

- The political condition in the U.S.A. is more conducive. In previous study, the survey which was sent out to middle eastern countries, the impact of political conditions was rated as high and very high (Elwakil et al., 2009).

- The Hierarchical Fuzzy Model proposed is based on the expert opinions of industry professionals. It is necessary to establish certain parameters or rubric following which they answer the questionnaire. The personal bias leads to extensive outliers, thus making the model inefficient.

- It is also observed that majority of participants have rated the employee culture environment of their respective organization as high and very high. However, the rating for employee compensation is low. This either represents that the employees of these organizations are not paid well or the participants favor a better employee culture environment over employee compensation. This represent personal bias in the responses.

5.3 Limitations

The developed model uses AHP to shortlist qualitative factors and hierarchical fuzzy expert system technique to assess the organizational performance. There are some inherent limitations in this model such as:

- The critical success factors have been shortlisted from literature review and the impact rating from participants. There is possibility that a factor could be left out if the frequency of appearance is low.

- Furthermore, based on geographical conditions and socio-economic conditions the model can only predict ranking of organizations that fall in that geographic location.

- The total number of collected questionnaires is 130. However, the usable data was only 90. The model accuracy can be improved by increasing the number of participant responses which are used to develop knowledge based rules of the fuzzy expert system.

- The more the data collected, the more accurate will be the results as the number of training rules will also increase. Furthermore, if the data should be collected from companies that are wide across the range of ranking.

- Majority of the construction firms from which responses were received were not publicly listed. This limited the number key financial performance indicating factors that could be included in the model.

- Due to technical constraints only the second layer of hierarchical fuzzy expert model could be developed in Matlab R2015. The first layer was manually calculated to compute the combined impact of sub-factors in sub-model.

- The input membership was Gaussian membership in the second layer of fuzzy expert system and the crisp output values were fuzzified again and assigned Gaussian membership. In the process, the model loses its accuracy.

- The data collected focused on companies that were present during the Purdue Building Construction Management Career Fair. It can be seen that the majority of companies are from Midwest, thus the responses received were clustered around certain organization ranking. Such data set limits the train-ability of the system.

- Furthermore, the model can only predict the category of the rank, not exact rank. To be able to make the model more accurate, data over wide range of rank needs to be collected.

5.4 Recommendation and Future works

The developed research/model benefits both researcher and practitioners to predict accurate company performance. Some of the recommendation and future works that can enhance the model and the research in general are listed below:

- Develop rubrics for survey participants to rate their opinion without bias.
- Collect quantitative information to validate the responses to qualitative questions.
- Include more quantitative financial factors to improve the accuracy of model by assessing the overall performance.
- to reduce personal bias multiple participants from the same organizations should participate in the survey.
- The study shows a need for further investigation on critical success factor to select the optimum number and nature for modeling the organizations performance.
- The end results of this research will lead to a new generation of specific and accurate company performance model and fully automated models/systems that might partially replace the expert opinion techniques.

APPENDICES

APPENDIX A. RESEARCH SURVEY QUESTIONNAIRE

Assessing Impact of Critical Success Factors on Overall Organizational Performance

Dr. Emad Elwakil and Zenith Rathore

School of Construction Management, Purdue University

Please enter your information below*:

1. Your Total experience in construction industry (in years):
2. Select your present designation in company:
   (a) Project Engineer/ Field Engineer
   (b) Project Manager
   (c) Estimator
   (d) Superintendent
   (e) HR/Administrative
   (f) Other (please specify)
3. Name of your present company*:
   **This information will not be reported in results. Any identifiable information will be coded and confidentiality will be maintained.*

Please provide you expert opinion for the following on a scale of one to five:

COLUMN 1: Please rate the level of IMPACT of factor on organizational performance.

COLUMN 2: Please rate the level of IMPLEMENTATION of the factor in your current organization Where, 1=Very Low 2= Low 3=Moderate 4=High 5= Very high

Table A.1: Response Table

		COLUMN 1	**COLUMN 2**
Categories	**Critical Success Factors**	**Impact**	**Implementation**
Administrative & Legal	Clear Vision, Mission & Goals		
	Competition Strategy		
	Organizational Structure		
	Political Conditions		
	No of Full Time Employees		
Technical	Usage of International Aspects (ISO)		
	Availability of knowledge		
	Usage of IT		
	Business Experience (no. of years)		
	Product Maintenance		
Management	Employee Culture Environment		
	Employee Compensation and Motivation		
	Applying Total Quality Management		
	Training		
Market & Finance	Quick Liquid Assets		
	Feedback Evaluation		
	Research and Development		
	Market Conditions/ Customer Engagement		

APPENDIX B: INSTITUTIONAL REVIEW BOARD(IRB) PROTOCOL

PU

Protocol #: 1603017499 **Expiration Date:**

Investigator: ELWAKIL, EMAD **Last Approval Date:**

Status: Exempt **Sequence Number:** 1

Purdue University
IRB Protocol Summary

Protocol Details

Title:	FRAMEWORK FOR ORGANIZATIONAL PERFORMANCE ASSESSMENT IN THE CONSTRUCTION INDUSTRY
Protocol Type:	Request for Exemption
Application Date:	03/30/2016
Reference Num 1:	

Organizations

Type	Organization	Address
Performing Organization	Purdue University	Purdue University 155 S GRANT STREET WEST LAFAYETTE IN - 479072114 USA

Investigators

Person Name	Units		Affiliate	Training Flag
ELWAKIL, EMAD	41904000	School of Construction Management	Faculty	N
RATHORE, ZENITH	41904000	School of Construction Management	Non-Faculty	N

PU

Protocol #:	1603017499	**Expiration Date:**	
Investigator:	ELWAKIL, EMAD	**Last Approval Date:**	
Status:	Exempt	**Sequence Number:**	1

Correspondents

Areas of Research

Code	Description
000001	All Research Areas

Subjects

Subject	Count
--	150

Questionnaire

Questionnaire Name:	Exemption Request - All Categories	**Prinicipal Investigator:**	ELWAKIL, EMAD
Protocol Number:	1603017499	**Title:**	FRAMEWORK FOR ORGANIZATIONAL PERFORMANCE ASSESSMENT IN THE CONSTRUCTION INDUSTRY

In order to request an exemption, investigators must complete and submit the Exemption Request Questionnaire. To qualify for exemption from IRB review, the ONLY involvement of human subjects must fall neatly within one or more of the exemption categories. The questionnaire captures the information necessary for IRB reviewers to make a determination about the proposed study. Exemption Requests submitted without the completed questionnaire will be rejected and returned to the PI for completion. Select "Yes" to complete the questionnaire. If you do not wish to request an exemption, select "No" to close the questionnaire.

Yes

[1] Which of the following best describes your study? Select one.

None of the above describes my study.

[1.4a] Does this study pose more than minimal risk to study subjects?

No

[1.4b] Does this study include collection of any of the following sensitive information? Select all that apply.

None of the above

[2.1] Are you requesting an exemption under Category 4 - Research involving the use of existing data, documents, records, pathological specimens or diagnostic specimens, either publicly available or recorded without information which would identify the human subjects?

No

[2.2] Are you requesting an exemption under Category 6 - Research involving taste and food quality evaluation and consumer acceptance studies of food?

No

[2.3] Are you requesting an exemption under Category 5 - Research and demonstration projects conducted by or subject to the approval of federal departments or agencies and which are designed to study or evaluate public benefit or service programs? This category is not applicable to state or local programs.

No

[2.4] Are you requesting an exemption under Category 2 - The research is limited to ONLY the use of survey procedures, interview procedures, observation of public behavior or use of educational tests?

Yes

[6] Age restrictions apply to this Category. Does the study involve children as research subjects? Children are defined as individuals who have not reached the age of majority under the applicable law of the jurisdiction in which the study will be conducted. For example, the age of majority is 18 years of age in many, but not all, U.S. states.

No

[6.2] Are the study activities limited to one or more of the following: surveys / questionnaires, interviews, focus groups, observation of public behavior, and/or use of educational tests (standardized cognitive, diagnostic, aptitude, achievement)?

Yes

[6.3] Do the study activities involve research subjects completing a task? Tasks include, but are not limited to, viewing media, playing a game, computer tasks or using a computer program, doing internet searches, "think aloud" or "imagine" tasks, or reading/writing tasks (except when completing surveys or educational tests).

No

[6.4] Will the information obtained be recorded in such a manner that subjects can be identified by direct identifiers, a combination of indirect identifiers, codes or other means?

No

[2.5] Are you requesting an exemption under Category 3 -The research involves ONLY survey procedures, interview procedures, observation of public behavior or use of educational tests (standardized cognitive, diagnostic, apitude, achievement) that is not exempt under Category 2 IF (1) OR (2) is TRUE: (1) the human subjects are elected or appointed public officials or candidates for public office; OR (2) federal statute(s) require(s) without exception that the confidentiality of personnally identifiable information will be maintained throughout the research and thereafter?

No

[2.6] Are you requesting an exemption under Category 1 - Research conducted in established or commonly accepted educational settings and involving normal educational practices?

No

[9] To ensure you are directed only to questions that apply to your study, please select the category or categories of exemption you are requesting.

Category 2

[9.2] Describe the purpose of this study specifying the hypothesis or goal and what research questions you will address to test your hypothesis or accomplish your goal. Avoid acronyms, technical terms and discipline-specific jargon. Use lay language so reviewers unfamiliar with your area of research can understand your description of this study.

The purpose of the study is to understand the impact of critical success factors on overall organizational performance. The potential success factors are collected from the literature review. The study will include a survey seeking expert opinion from construction professionals on the importance or impact of a critical success factors on the overall organizational performance. Based on results, these critical success factors will be shortlisted. The collected data will be analyzed using a Fuzzy modelling approach to build a prediction model.

[9.2a] What is the anticipated end date of this study?

04/30/2017

[9.3] Will the study include children as subjects? Children are defined as individuals who have not reached the age of majority under the applicable law of the jurisdiction in which the study will be conducted. For example, the age of majority is 18 years of age in many, but not all, U.S. states.

No

[9.3c] Describe all subject populations to be recruited for this study. Include in your description characteristics of the subject population as well as inclusion and exclusion criteria.

The subject populations for this study will be industry professional from construction industry with experience of more than one year. Responses from subjects working in a general contractor type company will be included in the study. The subjects will be asked to rate the impact of critical success factors that impact organizational performance.

[9.4] The consent process begins with recruitment, how eligible people are found and contacted for study participation. Do investigators have a prior relationship with the potential subjects? Select one.

No prior relationship with the potential subjects.

[9.4d] How will potential subjects be identified? In other words, how will you identify individuals and/or obtain names and contact information (e.g., referrals, email lists, recruitment database, etc.)?

Snowball sampling or other referrals.
Publicly available sources (e.g., school or business directory information, etc.). Public sources are available to the general public without restriction or password/passcode.
Other

[9.4d.2] How will you identify the potential subjects?

Co-investigator has interacted with industry professionals in career fairs. She has mentioned the study and received business cards from industry professionals who are willing to participate.

[9.4e] How will you inform potential subjects about the research? Identify all recruitment methods that will be used. See More for specific guidance on recruitment methods.

To recruit participants, Co-investigator interacted with industry professionals from construction companies at their booths during the Building Construction Management job fair held on February 17th. Participants were informed about the research work and were asked if they would be willing to participate in a survey about impact of critical success factors on organizational performance. Willing participants shared their business cards and information (e-mail ids) to send them the questionnaire. The co-investigator is also in touch with working professionals who are pursuing an online Masters program from School of Construction Management.Subjects willing to participate in the survey will also be emailed the questionnaires.

[9.4f] Who will approach/contact subjects about the research?

Co-investigator

[9.4g] After completing the questionnaire, a copy of all recruitment materials that will be used must be uploaded to the Attachments screen for submission with this application. Please refer to the CoeusLite Naming Conventions for Attachments document on the Forms Page of the Purdue IRB Website for guidance. Select Yes to proceed.

Yes

[9.5] Will subjects be asked to participate (i.e., provide consent)?

Yes

[9.5b] How will consent be obtained?

Information sheet will be provided to all study subects

[9.5c] Who will conduct the consent process?

Co-investigator

[9.5d] Will children (minors under age 18) be subjects in this study?

No

[9.5f] Is there a reasonable likelihood of recruiting individuals. including parents/legal guardians, whose primary language is not English?

No

[9.5g] Is there a possibility of encountering literacy issues or other language problems that could limit an individual's, including parents'/legal guardians', ability to understand about the study?

No

[9.5h] All consent materials must be uploaded to the Attachments screen and submitted with this application. When uploading these materials use Document Type = Consent Documents.

Yes

[9.6] Identify all payments or other incentives provided to subjects for their participation in this study. Select all that apply.

No subject payments or incentives will be provided

[9.7] Describe what steps will be taken to ensure subject privacy during data collection. Consider the circumstances and nature of information to be obtained taking into account factors (e.g., age, gender, ethnicity, education level, etc.) that may influence subjects' expectations of privacy.

Industry professionals´ and companies´ survey are confidential, and no names will be disclosed. Only company name will be included in questionnaire, which will be coded to an unidentifiable nomenclature. All publishing will be in aggregate form and all identifiers will be removed.

[9.7a] To what degree will study data be identifiable? Select one.

Anonymized / Deidentified - Identifiers will be collected or obtained, but they will be removed before data are used in the study.

[9.7b] Can subject identities reasonable be deduced from those data used for the study?

No

[9.8] Select all performance site locations.

Location(s) within the United States

[9.8a] Identify the performance site locations, including institution name, city and state.

The surveys will be emailed to subjects and it will be conducted online.

[10] Do you, or any other personnel listed on this protocol, have any financial interests and/or potential or real conflicts of interest related to this study?

No

[A] Did you find that you were unable to add certain personnel to the Investigators/Study Personnel tab? If so, please list the missing study personnel below along with their role, email address and phone numbers. If you have entered all personnel successfully on this protocol, please enter N/A.

N/A

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